

PRODUCTION OF SINTERED ALUMINUM NITRIDE

Patent Number: JP2275765
Publication date: 1990-11-09
Inventor(s): NAKANO TADASHI; others: 06
Applicant(s): KAWASAKI STEEL CORP
Requested Patent: ☐ JP2275765
Application Number: JP19890095385 19890417
Priority Number(s):
IPC Classification: C04B35/58
EC Classification:
Equivalents:

Abstract

PURPOSE: To produce a sintered AlN having dense texture and high thermal conductivity and electrical resistance and suitable as an insulation substrate, at a low cost, by adding a specific sintering assistant to AlN powder, forming the mixture and calcining in a non-oxidizing atmosphere.

CONSTITUTION: The objective sintered AlN is produced by mixing 100 pts.wt. of AlN powder with (A) 0.05-5 pts.wt. (in terms of oxide) of one or more components selected from Y, Sc and lanthanoid and (B) 0.01 to 5 pts.wt. of one or more elements selected from metallic Li, metallic Be, metallic Mg, B, Si, S, P, As and metallic Zn, forming the mixture and calcining at 1400 to 2000 deg.C in a non-oxidizing atmosphere.

Data supplied from the esp@cenet database - I2

1. Title of the Invention

METHOD FOR PRODUCING ALUMINUM NITRIDE SINTERED BODY

2. Claims

1. A method for producing an aluminum nitride sintered body, comprising: adding, as a sintering aid, (A) 0.05 to 5 parts by weight of one or not less than two kinds selected from the group consisting of oxides of yttrium, scandium, and lanthanides in terms of oxides, and (B) 0.01 to 5 parts by weight of one or not less than two kinds of single substances selected from the group consisting of metal lithium, metal beryllium, metal magnesium, boron, silicon, sulfur, phosphorus, arsenic and metal zinc to 100 parts by weight of an aluminum nitride powder; forming the mixed powders; and firing the formed body at a temperature in a range of 1400°C to 2000°C in non-oxidizable atmosphere.

2. The method for producing an aluminum nitride sintered body according to claim 1, comprising: further adding, as a sintering aid, (C) 0.01 to 5 parts by weight of one or not less than two kinds selected from the group consisting of alkali metal oxides and alkali metal compounds to be converted to oxides by heating at a temperature of 2000°C or less as well as oxides of boron, silicon, germanium, arsenic and phosphorus and compounds to be their oxides by heating at a temperature of 2000°C or less in terms of oxides to 100 parts by weight of the aluminum nitride powder.

3. The method for producing an aluminum nitride sintered body

according to claim 1, comprising: further adding, as a sintering aid, (D) 0.01 to 5 parts by weight of one or not less than two kinds of compounds selected from the group consisting of metal borides, metal nitrides, metal phosphides, metal sulfides, metal silicides, and metal hydrides to 100 parts by weight of the aluminum nitride powder.

4. The method for producing an aluminum nitride sintered body according to claim 2, comprising: further adding, as a sintering aid, (D) 0.01 to 5 parts by weight of one or not less than two kinds of compounds selected from the group consisting of metal borides, metal nitrides, metal phosphides, metal sulfides, metal silicides, and metal hydrides to 100 parts by weight of the aluminum nitride powder.

5. The method for producing an aluminum nitride sintered body according to claim 1, comprising: further adding, as a sintering aid, (E) 0.01 to 2 parts by weight of one or not less than two kinds of compounds selected from oxides of aluminum, gallium, indium, tungsten, bismuth, lead, antimony, cadmium and zinc and compounds to be converted to their oxides by heating at a temperature of 2000°C or less in terms of oxides to 100 parts by weight of the aluminum nitride powder.

6. The method for producing an aluminum nitride sintered body according to claim 5, comprising: further adding, as a sintering aid, (C) 0.01 to 5 parts by weight of one or not less than two kinds selected from the group consisting of alkali metal oxides and alkali metal compounds to be

converted to oxides by heating at a temperature of 2000°C or less as well as oxides of boron, silicon, germanium, arsenic and phosphorus and compounds to be their oxides by heating at a temperature of 2000°C or less in terms of oxides to 100 parts by weight of the aluminum nitride powder.

7. The method for producing an aluminum nitride sintered body according to claim 5, comprising: further adding, as a sintering aid, (D) 0.01 to 5 parts by weight of one or not less than two kinds of compounds selected from the group consisting of metal borides, metal nitrides, metal phosphides, metal sulfides, metal silicides, and metal hydrides to 100 parts by weight of the aluminum nitride powder.

8. The method for producing an aluminum nitride sintered body according to claim 6, comprising: further adding, as a sintering aid, (D) 0.01 to 5 parts by weight of one or not less than two kinds of compounds selected from the group consisting of metal borides, metal nitrides, metal phosphides, metal sulfides, metal silicides, and metal hydrides to 100 parts by weight of the aluminum nitride powder.

3. Detailed Description of the Invention

Field of the Invention

The present invention relates to a method for producing an aluminum nitride sintered body and, more particularly, to a method for producing an aluminum nitride sintered body with a thermal conductivity high enough to satisfy the industrial requirements.

Prior Art

The use of an AlN sintered body with a high thermal conductivity is practically the use as an insulating material such as a substrate material for a semiconductor.

Along with the tendency of high integration, high speed, and high output power of semiconductors, the following problems have been drawing attentions. That is:

(1) how efficiently the heat radiated from a semiconductor chip can be released to outside of the system:

(2) delay of signals in a substrate or a package part becomes a problem following the improvement of the operation speed:

(3) the reliability of junction between a chip and a substrate is deteriorated owing to the increase of thermal expansion difference between them along with the enlargement of the chip size: and

(4) dielectric breakdown of a substrate tends to be a serious problem since the voltage to be used for a high power chip is more and more increased.

In place of conventional alumina, a ceramic for a substrate and a package which is capable of solving such problems of semiconductors is preferable to have the following properties:

- (1) a thermal conductivity is high;
- (2) an electric insulation is excellent;
- (3) high frequency properties are desirable (a low dielectric constant, a low dielectric loss);
- (4) a thermal expansion coefficient is close to that of Si or GaAs;

- (5) chemical stability is good;
- (6) mechanical strength is high;
- (7) circuit formation is easy; and
- (8) air-tight sealing is possible.

As a material basically having such properties, AlN is supposed to be promising one.

However, in the case of practical application of an AlN ceramic, the following minimum characteristic items have to be satisfied. That is,

(1) it is preferable that a sintered body is uniform and dense and has high mechanical strength and a relative density of 95% or higher:

(2) the thermal conductivity is as high as possible:

(3) the volume resistivity is high and required to be $10^{12} \Omega \cdot \text{cm}$ or higher: and

(4) the surface of the sintered body is smooth and flat.

Among the above-mentioned characteristic items, the item (4) is said not indispensable, however in the case of production of a substrate by mass production, such a characteristic is advantageous to eliminate processes and lower the production cost and in terms of the production technique, it is indispensable. Practically, it is desirable that the surface roughness Ra as fired is $0.5 \mu\text{m}$ or lower and the warp is $0.1 \text{ mm}/50 \text{ mm}$ or less.

By a conventional technique, in order to satisfy the above-mentioned items (1) and (2), as described in Japanese Examined Patent Publication No. 46-41003, Y_2O_3 is used as a sintering aid or as described in Japanese Examined Patent Publication No. 58-49510, CaO , BaO , SrO and the like are used as sintering aids to obtain ceramics with a thermal conductivity of

about 100 W/m•K. However, users require a sintered body having further higher thermal conduction properties based on the applications.

As methods for obtaining sintered bodies with a high thermal conductivity, the following have been proposed:

(i) a method involving thermally treating an AlN powder at 1600°C or higher in non-oxidizable atmosphere to lower the oxygen content in the powder and then sintering the powder (Japanese Unexamined Patent Publication Sho. 61-201668): and

(ii) a method involving hot-pressing an AlN powder at 1800 to 2300°C in a pressure of 20 kg/cm² or higher and non-oxidizable atmosphere after thermal treatment to obtain a thermal conductivity at highest 210 W/m•K (Japanese Unexamined Patent Publication No. 61-201668).

However, these methods are not suitable for mass production since the property of sintering difficulty of AlN becomes significant for removal of a thin oxide film on the AlN surface layer to result in low productivity even if a sintering aid is added and impossibility of obtaining a desired sintered body unless costly hot pressing method is employed.

Further, "Journal of Ceramic Society", 25th Basic Discussion on Ceramics, 1DO3, 3HO3 (Jan. 1987) discloses a method for obtaining an AlN sintered body with a high thermal conductivity by firing an AlN formed body at 1850 to 1950°C for 2 to 96 hours in reducing atmosphere, however even by this method, no sintered body to be an AlN substrate excellent in the high thermal conduction properties can be obtained.

On the other hand, Japanese Unexamined Patent Publication No. 62-52181 discloses a method for producing an AlN sintered body involving

sintering a formed body of AlN mixed with carbon 0.2 to 3.4 parts by weight on the basis of carbon and yttrium oxide 0.1 to 10 parts by weight as sintering aids at a temperature of 1600 to 2100°C. However, the present invention does not refer at all to the following points and owing to the following problems, the method cannot be said to be a satisfactory method for producing an AlN substrate.

- (1) the density of a sintered body is low:
- (2) no electric insulation property is obtained: and
- (3) coloration and sintering unevenness occur.

Further, techniques of adding a sintering aid of AlN, Y_2O_3 , and C as auxiliary agents are disclosed in Japanese Unexamined Patent Publication Sho. 61-127667 and 61-219763; however, because of the reason similar to those described above, they are not suitable to obtain AlN substrates. Further, that is same as described above with respect to Japanese Unexamined Patent Publication No. 63-236765.

Problems to be Solved by the Invention

With respect to sintered bodies by the above-mentioned conventional methods, they have following problems:

- (a) the thermal conductivity is insufficient;
- (b) installation cost for hot press or the like is high and sintering can be carried out only by a furnace with a low productivity;
- (c) no electric insulation property is provided; and
- (d) no stable property can be obtained. As described above, it can be hardly said that the conventional inventions developed before are satisfactory to satisfy all of the above-mentioned four items (a) to (d).

Accordingly, in order to improve such points, it has been highly expected to develop an innovative method for producing an AlN sintered body with a high thermal conductivity.

It is an object of the present invention to provide a method for giving a high thermal conductivity of an AlN sintered body while satisfying all of the above-mentioned problems described in four items (a) to (d). That is, an object of the present invention is to provide a method for producing an economical AlN sintered body which is dense and has high thermal conductivity and electric resistance and suitable properties as a material for such as an electric insulation substrate.

Means for Solving the Problems

Taking the above-mentioned problems on conventional techniques into consideration, the present inventors have repeatedly made investigations in order to improve the thermal conductivity of an aluminum nitride sintered body and provide characteristics necessary as a substrate and consequently have found the new facts as follows and completed the present invention.

That is, when a sheet-like formed body, which is obtained by adding one or not less than two kinds of single substances selected from the group consisting of REM and metal lithium, metal beryllium, metal magnesium, boron, silicon, sulfur, phosphorus, arsenic and metal zinc to an AlN powder, is sintered in a non-oxidizable atmosphere, a ceramic sintered body with a high thermal conductivity can be obtained. Herein, REM denotes yttrium, scandium, and lanthanides.

The above-mentioned sintered body satisfies all of the

above-mentioned requirements (a) to (d) which are required for the above-mentioned insulation substrate.

Based on the facts, a wide range of investigations have been made with respect to the optimum addition ranges for the above-mentioned requirements and other elements and compounds and consequently, the present invention has been completed. If additional elements and their compounds and the addition ranges of them are properly restricted and selected, an aluminum nitride-based highly thermally conductive and electrically insulating sintered body with a relative density of 95% or higher, a thermal conductivity of 160 W/m•K or higher, a surface roughness Ra of the surface after firing 0.5 μm or lower, and a volume resistivity of $10^{12} \Omega\text{cm}$ or higher can be obtained.

That is, such a sintered body can be obtained by adding sintering aid of components selected from a group consisting of the following (A) to (E) in combinations to 100 parts by weight of an aluminum nitride powder, forming the obtained mixture, and firing the formed body at a temperature in a range of 1400 to 2000°C in non-oxidizable atmosphere. Groups of these components are as follows:

(A) 0.05 to 5 parts by weight of one or not less than two kinds selected from the group consisting of oxides of yttrium, scandium, and lanthanides in terms of oxides;

(B) 0.01 to 5 parts by weight of one or not less than two kinds of single substances selected from the group consisting of metal lithium, metal beryllium, metal magnesium, boron, silicon, sulfur, phosphorus, arsenic and metal zinc;

(C) 0.01 to 5 parts by weight of one or not less than two kinds selected from the group consisting of alkali metal oxides and alkali metal compounds to be converted to oxides by heating at a temperature of 2000°C or less as well as oxides of boron, silicon, germanium, arsenic and phosphorus and compounds to be their oxides by heating at a temperature of 2000°C or less in terms of oxides;

(D) 0.01 to 5 parts by weight of one or not less than two kinds of compounds selected from the group consisting of metal borides, metal nitrides, metal phosphides, metal sulfides, metal silicides, and metal hydrides; and

(E) 0.01 to 2 parts by weight of one or not less than two kinds of compounds selected from oxides of aluminum, gallium, indium, tungsten, bismuth, lead, antimony, cadmium and zinc and compounds to be converted to their oxides by heating at a temperature of 2000°C or less in terms of oxides.

The combinations of the above-mentioned groups of the components are as follows:

- (1) (A) + (B);
- (2) (A) + (B) + (C);
- (3) (A) + (B) + (D);
- (4) (A) + (B) + (C) + (D);
- (5) (A) + (B) + (E);
- (6) (A) + (B) + (E) + (C);
- (7) (A) + (B) + (E) + (D); and
- (8) (A) + (B) + (E) + (C) + (D).

Functions

The mechanism of the way how the combined additions of these sintering aids are effective is not sufficiently made clear, however it is supposed as follows.

In the surface layer of AlN, some kinds of Al oxides although they do not form complete Al_2O_3 exist. Assuming these oxides to be Al_2O_3 , together with the foregoing added components (A), for example, Y_2O_3 , a liquid phase $x\text{Al}_2\text{O}_3\text{-}y\text{Y}_2\text{O}_3$ is produced. Next, any of the components (B), metal lithium, metal beryllium, metal magnesium, boron, silicon, sulfur, phosphorus, arsenic and metal zinc, is a strong reducing agent and causes a reaction with impurity, oxygen, in the aluminum nitride to remove the impurity. That is, in a step from the production of the liquid phase to grain growth, while oxygen in the AlN surface being reduced by the foregoing components (B), the AlN particles can be cleaned.

It is supposed that the sintered body obtained consequently is one ideal as a sintered body for a highly thermally conductive and electrically insulating substrate.

If the addition amount of the foregoing components (A) is less than 0.05 parts by weight to 100 parts by weight of AlN, the thermal conductivity is not so increased and therefore, the requirement is not satisfied. If it is more than 5 parts by weight, the grain boundary phase is increased and also the thermal conductivity is decreased.

Further, the addition amount of the foregoing components (B), that is, reducing agent components, is less than 0.01 parts by weight to 100 parts by weight of AlN, the distribution of the grain boundary phase become

uneven and stripe-like patterns are formed. If it is more than 2 parts by weight, YN remains and partial coloration takes place to deteriorate the appearance. If the addition amount is further increased, the shrinking rate at the time of temperature increase becomes high and the grain boundary phase is evaporated and therefore sintering cannot be carried out well.

Next, if the components (C) are added to the forgoing components (A) and components (B), since the components (C) are alkali metal oxides or glass forming element oxides, they produce liquid phase at a low temperature and therefore contribute to sintering promotion owing to the liquid phase in grain boundaries, remove the oxides in the surface of AlN and further make the grain boundaries uniform owing to glass formation and suppress abnormal growth of AlN crystal grains owing to penetration. Accordingly, it is made possible to obtain a sintered body with a uniform grain size, a high thermal conductivity, a high density, a high insulating resistance, and little dispersion of metallizing property.

If the amount of the components (C) is less than 0.01 parts, uneven firing easily occurs attributed to unevenness of the distribution of the remaining grain boundary phase. If it is more than 5 parts by weight, abnormal grain growth is found taking place at the time of sintering to result in low mechanical strength.

Further, if components (D), that is, metal borides, metal nitrides, metal phosphides, metal sulfides, metal silicides, and metal hydrides, are added to the foregoing component (A) and component (B), they are all easy to form compounds with oxygen and cause reaction with impurity, oxygen, in the AlN crystal to remove the impurity and simultaneously, the reaction

products become liquid phase and penetrate grain boundaries and thus the components exhibit the effect to promote sintering.

The components (A) added together promote sintering while forming liquid phase at a high temperature. Further, the components (B) form compounds with oxygen to evaporate oxygen in the grain growth step owing to the strong reducing function to result in further improvement of the thermal conductivity of AlN.

The addition amount of the foregoing components (D) is 0.01 to 5 parts by weight to 100 parts by weight of AlN. If it is less than 0.001 parts by weight, the impurity oxygen removal effect is insufficient and even if more than 5% by weight of the components are added, the addition effect is not improved.

Further, the components (C) and the components (D) are added in combination to the foregoing components (A) and component (B), owing to the multiplied effects of the effect to decrease oxygen and the effect to decrease the liquid phase formation temperature, an AlN substrate with a high thermal conductivity can be obtained. In this case, the addition amounts of the components (C) and the components (D) are set to be respectively 0.01 to 5 parts by weight to 100 parts of AlN.

In place of the components (C) and the components (D), the components (E), that is, oxides of aluminum, gallium, indium, tungsten, bismuth, lead, antimony, cadmium, and zinc, are added to the foregoing components (A) and component (B), so that AlN with a high thermal conductivity can be obtained. The function of the components (E) can be supposed as follows.

The compounds of the components (E) cause reaction with impurities such as Fe, Ti and the like existing in AlN during sintering process to form compounds in grain boundaries and trap them. Fe, Ti, and the like existing in AlN interfere thermal conduction and by removing them, the thermal conductivity can be improved.

The addition amount of the components (E) is 0.01 to 5 parts by weight to 100 parts by weight of AlN. If less than 0.01 parts by weight, the effect to produce compounds by reaction with Fe, Ti and the like is insufficient and even if addition exceeds 5% by weight, the effect of the addition cannot be improved.

Quaternary or pentanary sintering aids composed of the foregoing components (A), components (B), and components (E) together with the components (C) and/or the components (D) are also effective. In this case, the characteristics of the respective components are extracted and owing to the multiplied effects, the thermal conductivity of AlN can be improved.

Next, a practical example of a method for producing a product of the present invention will be described while using Y_2O_3 as a component (A) and metal Zn as a component (B).

To 100 parts by weight of an aluminum nitride powder with an average particle diameter of 0.1 to 3 μm , 0.5 to 5 parts by weight of Y_2O_3 and 0.01 to 0.5 parts by weight of metal Zn are added, mixed together and dispersed and further after being mixed with a binder, the mixture is formed. As a forming method, commonly known methods such as a doctor blade method, a press-forming method, a casting forming method, an extrusion forming method and the like can be employed. The formed body obtained

in such a manner is fired at 1400 to 2000°C in non-oxidizable atmosphere.

In order to obtain an aluminum nitride sintered body with a high thermal conductivity, it is more preferable if impurity oxygen is less, however it is acceptable that the impurity oxygen is less than about 1 parts by weight.

Firing is carried out in an AlN crucible and if the firing temperature is 1400°C or lower, sintering is stopped in middle and micropores are formed attributed to sublimation of AlN particles to result in decrease of the thermal conductivity.

If firing is carried out in atmosphere with an oxygen concentration of 500 ppm or higher, oxidation of AlN takes place to make it impossible to obtain a highly thermally conductive sintered body.

Effects of the Invention

The present invention can provide an aluminum nitride sintered body having a thermal conductivity of 160 W/m•K or higher and an electrical insulator using the sintered body as a substrate and the sintered body and the insulator can be applied to industrial use such as a substrate for a hybrid IC, a substrate for surging, heat sinks for a power transistor, a power diode, a laser diode and the like.

Examples

Example 1

To 100 parts by weight of an AlN powder with an average particle size of 1 μm , Y_2O_3 with an average particle size of 1 μm and a magnesium powder with an average particle size of 1 μm in the amounts respectively shown in Table 1 were added together with a toluene-ethanol mixed solvent,

sufficiently mixed by a ball mill and pulverized and after that, polyvinyl butyral resin was added as a binder to obtain AlN slurries. Using the slurries, green sheets were formed by a doctor blade method and punched into a size of 65×65 mm square to obtain green formed bodies.

After being degreased at 700°C in N_2 , they were fired at 1800°C for 3 hours in N_2 atmosphere to obtain AlN plates.

With respect to the obtained AlN plates, characteristics generally required for insulating substrates such as the appearance, the relative density, the thermal conductivity, the insulation resistance, the surface roughness or the like were measured. The results are shown in Table 1.

Among the characteristics, the relative density was calculated by measuring the densities of the sintered bodies by Archimedes's method and dividing the densities by the true density and expressed by %.

The thermal conductivity was measured by employing a laser flash method. The insulation resistance was measured by using an insulation measuring meter. The surface roughness (R_a) was measured by a probe type surface roughness measuring meter.

Example 2

AlN plates were produced in the same manner as the Example 1, except that the respective elements shown in Table 2 were used in place of the Mg powder among the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 2.

Example 3

AlN plates were produced in the same manner as the Example 1,

except that the respective rare earth oxides shown in Table 3 were used in place of Y_2O_3 among the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 3.

Example 4

To 100 parts by weight of an AlN powder with an average particle size of $1\ \mu m$, Y_2O_3 with an average particle size of $1\ \mu m$, B with an average particle size of $3\ \mu m$, and the respective oxides shown in Table 4 in the amounts respectively shown in Table 4 were added together with a toluene-ethanol mixed solvent, sufficiently mixed by a ball mill and pulverized and after that, polyvinyl butyral resin was added as a binder to obtain AlN slurries. Using the slurries, green sheets were formed by a doctor blade method and punched into a size of $65 \times 65\ mm$ square to obtain green formed bodies.

After being degreased at $700^\circ C$ in N_2 , they were fired at $1800^\circ C$ for 3 hours in N_2 atmosphere to obtain AlN plates.

With respect to the obtained AlN plates, characteristics generally required for insulating substrates such as the appearance, the relative density, the thermal conductivity, the insulation resistance, the surface roughness or the like were measured. The results are shown in Table 4.

Among the characteristics, the relative density was calculated by measuring the densities of the sintered bodies by Archimedes' method and dividing the densities by the true density and expressed by %.

The thermal conductivity was measured by employing a laser flash method. The insulation resistance was measured by using an insulation

measuring meter. The surface roughness (Ra) was measured by a probe type surface roughness measuring meter.

Example 5

To 100 parts by weight of an AlN powder with an average particle size of 1 μm , Y_2O_3 with an average particle size of 1 μm , B with an average particle size of 3 μm , and the respective compounds shown in Table 4 in the amounts respectively shown in Table 5 were added together with a toluene-ethanol mixed solvent, sufficiently mixed by a ball mill and pulverized and after that, polyvinyl butyral resin was added as a binder to obtain AlN slurries. Using the slurries, green sheets were formed by a doctor blade method and punched into a size of 65 \times 65 mm square to obtain green formed bodies.

After being degreased at 700°C in N_2 , they were fired at 1800°C for 3 hours in N_2 atmosphere to obtain AlN plates.

With respect to the obtained AlN plates, characteristics generally required for insulating substrates such as the appearance, the relative density, the thermal conductivity, the insulation resistance, the surface roughness or the like were measured. The results are shown in Table 5.

Among the characteristics, the relative density was calculated by measuring the densities of the sintered bodies by Archimedes' method and dividing the densities by the true density and expressed by %.

The thermal conductivity was measured by employing a laser flash method. The insulation resistance was measured by using an insulation measuring meter. The surface roughness (Ra) was measured by a probe type surface roughness measuring meter.

Example 6

AlN plates were produced in the same manner as the Example 5, except that Y_2O_3 , B, and respective compounds shown in Table 6 were used for the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 6.

Example 7

AlN plates were produced in the same manner as the Example 5, except that Y_2O_3 , B, and respective compounds shown in Table 7 were used for the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 7.

Example 8

AlN plates were produced in the same manner as the Example 5, except that Y_2O_3 , a Zn powder, and respective compounds shown in Table 8 were used for the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 8.

Example 9

AlN plates were produced in the same manner as the Example 5, except that Y_2O_3 , metal Li, and respective compounds shown in Table 9 were used for the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 9.

Example 10

AlN plates were produced in the same manner as the Example 5, except that Y_2O_3 , B, and respective compounds shown in Table 10 were used for the raw materials and the appearance, the relative density, the thermal conductivity, the insulation resistance, and the surface roughness of them were measured and the results are shown in Table 10.

Table 1

| No. | Y ₂ O ₃ parts by weight | Mg parts by weight | Thermal conductivity W/mK | Insulation resistance Ω cm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μ m) | Appearance | Remark |
|-----|---|--------------------------|---------------------------------|---|--------------------------------|--------------------------|--|----------------------|------------------------|
| 1 | 0.1 | 0 | 130 | $>10^{14}$ | 28 | 98.0 | 0.33 | Uneven coloration | Comparative Example |
| 2 | 0.1 | 0.05 | 175 | $>10^{14}$ | 30 | 99.1 | 0.28 | Good | Example |
| 3 | 0.1 | 0.10 | 179 | $>10^{14}$ | 30 | 99.4 | 0.30 | Good | Example |
| 4 | 0.1 | 0.30 | 188 | $>10^{14}$ | 31 | 99.5 | 0.31 | Good | Example |
| 5 | 0.1 | 0.50 | 181 | $>10^{14}$ | 30 | 99.7 | 0.30 | Good | Example |
| 6 | 0.1 | 2.00 | 192 | $>10^{14}$ | 31 | 99.8 | 0.30 | Good | Example |
| 7 | 1.0 | 0.05 | 203 | $>10^{14}$ | 33 | 99.9 | 0.32 | Good | Example |
| 8 | 1.0 | 0.10 | 210 | $>10^{14}$ | 34 | 99.8 | 0.33 | Good | Example |
| 9 | 1.0 | 0.30 | 214 | $>10^{14}$ | 33 | 99.9 | 0.33 | Good | Example |
| 10 | 1.0 | 0.50 | 218 | $>10^{14}$ | 33 | 100.0 | 0.34 | Good | Example |
| 11 | 2.0 | 0.05 | 214 | $>10^{14}$ | 36 | 100.0 | 0.34 | Good | Example |
| 12 | 2.0 | 0.10 | 218 | $>10^{14}$ | 34 | 100.0 | 0.35 | Good | Example |
| 13 | 2.0 | 0.30 | 220 | $>10^{14}$ | 35 | 100.0 | 0.33 | Good | Example |
| 14 | 2.0 | 0.50 | 221 | $>10^{14}$ | 33 | 100.0 | 0.35 | Good | Example |
| 15 | 2.0 | 2.00 | 218 | $>10^{14}$ | 34 | 100.0 | 0.34 | Good | Example |
| 16 | 3.0 | 0.05 | 200 | $>10^{14}$ | 35 | 100.0 | 0.38 | Good | Example |
| 17 | 3.0 | 0.10 | 199 | $>10^{14}$ | 36 | 100.0 | 0.36 | Good | Example |
| 18 | 3.0 | 0.30 | 204 | $>10^{14}$ | 39 | 100.0 | 0.37 | Good | Example |
| 19 | 3.0 | 0.50 | 206 | $>10^{14}$ | 32 | 100.0 | 0.36 | Good | Example |
| 20 | 3.0 | 2.00 | 199 | $>10^{14}$ | 34 | 100.0 | 0.38 | Good | Example |
| 21 | 5.0 | 0.05 | 190 | $>10^{14}$ | 31 | 99.2 | 0.39 | Good | Example |
| 22 | 5.0 | 0.10 | 191 | $>10^{14}$ | 34 | 99.2 | 0.38 | Good | Example |
| 23 | 5.0 | 0.30 | 188 | $>10^{14}$ | 34 | 99.2 | 0.40 | Good | Example |
| 24 | 5.0 | 0.50 | 186 | $>10^{14}$ | 33 | 99.0 | 0.42 | Good | Example |
| 25 | 5.0 | 2.00 | 180 | $>10^{14}$ | 32 | 99.1 | 0.40 | Good | Example |

Table 2

| No. | Y ₂ O ₃ parts by weight | Additive | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|---------------|----------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|------------------------------------|------------|
| | | | parts by weight | | | | | | |
| 1 | 2.0 | Li | 0.05 | 198 | >10 ¹⁴ | 34 | 100.0 | 0.36 | Good |
| 2 | 2.0 | Li | 0.50 | 190 | >10 ¹⁴ | 35 | 100.0 | 0.37 | Good |
| 3 | 2.0 | Li | 5.00 | 175 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 4 | 2.0 | Be | 0.05 | 230 | >10 ¹⁴ | 36 | 100.0 | 0.35 | Good |
| 5 | 2.0 | Be | 0.50 | 236 | >10 ¹⁴ | 39 | 100.0 | 0.32 | Good |
| 6 | 2.0 | Be | 5.00 | 233 | >10 ¹⁴ | 39 | 100.0 | 0.34 | Good |
| 7 | 2.0 | Si | 0.05 | 170 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 8 | 2.0 | Si | 0.50 | 172 | >10 ¹⁴ | 35 | 100.0 | 0.35 | Good |
| 9 | 2.0 | Si | 5.00 | 171 | >10 ¹⁴ | 32 | 100.0 | 0.34 | Good |
| 10 | 2.0 | B | 0.05 | 210 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 11 | 2.0 | B | 0.50 | 214 | >10 ¹⁴ | 31 | 100.0 | 0.35 | Good |
| 12 | 2.0 | B | 5.00 | 218 | >10 ¹⁴ | 32 | 100.0 | 0.34 | Good |
| 13 | 2.0 | S | 0.05 | 179 | >10 ¹⁴ | 34 | 100.0 | 0.35 | Good |
| 14 | 2.0 | S | 0.50 | 190 | >10 ¹⁴ | 38 | 100.0 | 0.35 | Good |
| 15 | 2.0 | S | 5.00 | 191 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 16 | 2.0 | As | 0.05 | 191 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 17 | 2.0 | As | 0.50 | 193 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 18 | 2.0 | As | 5.00 | 193 | >10 ¹⁴ | 32 | 100.0 | 0.34 | Good |
| 19 | 2.0 | P | 0.05 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.35 | Good |
| 20 | 2.0 | P | 0.50 | 208 | >10 ¹⁴ | 39 | 100.0 | 0.34 | Good |
| 21 | 2.0 | P | 5.00 | 211 | >10 ¹⁴ | 31 | 100.0 | 0.33 | Good |
| 22 | 2.0 | Zn | 0.05 | 207 | >10 ¹⁴ | 30 | 100.0 | 0.34 | Good |
| 23 | 2.0 | Zn | 0.50 | 209 | >10 ¹⁴ | 29 | 100.0 | 0.35 | Good |
| 24 | 2.0 | Zn | 5.00 | 208 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 25 | 2.0 | Zn B | 3.00 3.00 | 212 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 26 | 2.0 | Li B | 0.05 2.00 | 210 | >10 ¹⁴ | 37 | 100.0 | 0.37 | Good |
| 27 | 2.0 | P S | 1.00 1.00 | 222 | >10 ¹⁴ | 39 | 100.0 | 0.34 | Good |
| 28 | 2.0 | Li Zn B | 1.00 1.00 1.00 | 228 | >10 ¹⁴ | 38 | 100.0 | 0.31 | Good |

Table 3-1

| Additive | parts by weight | Mg parts by weight | Thermal conductivity W/m K | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|--------------------------------|-----------------|-----------------------|----------------------------------|---|--------------------------------|-----------------------|---|------------|
| La ₂ O ₃ | 0.01 | 1.0 | 184 | > 10 ¹⁴ | 30 | 99.8 | 0.33 | Good |
| | 0.10 | 1.0 | 231 | > 10 ¹⁴ | 32 | 99.9 | 0.33 | Good |
| | 1.00 | 1.0 | 232 | > 10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| | 2.00 | 1.0 | 223 | > 10 ¹⁴ | 36 | 100.0 | 0.36 | Good |
| | 5.00 | 1.0 | 225 | > 10 ¹⁴ | 31 | 100.0 | 0.37 | Good |
| CeO ₂ | 0.01 | 1.0 | 191 | > 10 ¹⁴ | 34 | 99.8 | 0.28 | Good |
| | 0.10 | 1.0 | 193 | > 10 ¹⁴ | 32 | 99.8 | 0.29 | Good |
| | 1.00 | 1.0 | 193 | > 10 ¹⁴ | 31 | 99.9 | 0.31 | Good |
| | 2.00 | 1.0 | 200 | > 10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| | 5.00 | 1.0 | 204 | > 10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| Nd ₂ O ₃ | 0.01 | 1.0 | 193 | > 10 ¹⁴ | 33 | 99.9 | 0.30 | Good |
| | 0.10 | 1.0 | 198 | > 10 ¹⁴ | 32 | 100.0 | 0.30 | Good |
| | 1.00 | 1.0 | 211 | > 10 ¹⁴ | 34 | 100.0 | 0.31 | Good |
| | 2.00 | 1.0 | 232 | > 10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| | 5.00 | 1.0 | 208 | > 10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| Sm ₂ O ₃ | 0.01 | 1.0 | 179 | > 10 ¹⁴ | 33 | 99.9 | 0.29 | Good |
| | 0.10 | 1.0 | 197 | > 10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| | 1.00 | 1.0 | 205 | > 10 ¹⁴ | 31 | 100.0 | 0.38 | Good |
| | 2.00 | 1.0 | 214 | > 10 ¹⁴ | 32 | 100.0 | 0.40 | Good |
| | 5.00 | 1.0 | 211 | > 10 ¹⁴ | 38 | 100.0 | 0.42 | Good |

Table 3-2

| Additive | parts by weight | Mg parts by weight | Thermal conductivity W/m K | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|--|----------------------|-----------------------|----------------------------------|---|--------------------------------|-----------------------|---|------------|
| Gd ₂ O ₃ | 0.01 | 1.0 | 183 | > 10 ¹⁴ | 29 | 99.9 | 0.33 | Good |
| | 0.10 | 1.0 | 193 | > 10 ¹⁴ | 31 | 100.0 | 0.32 | Good |
| | 1.00 | 1.0 | 218 | > 10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| | 2.00 | 1.0 | 209 | > 10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| | 5.00 | 1.0 | 194 | > 10 ¹⁴ | 34 | 100.0 | 0.39 | Good |
| Dy ₂ O ₃ | 0.01 | 1.0 | 187 | > 10 ¹⁴ | 34 | 99.9 | 0.31 | Good |
| | 0.10 | 1.0 | 190 | > 10 ¹⁴ | 35 | 99.9 | 0.32 | Good |
| | 1.00 | 1.0 | 215 | > 10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| | 2.00 | 1.0 | 218 | > 10 ¹⁴ | 34 | 100.0 | 0.36 | Good |
| | 5.00 | 1.0 | 209 | > 10 ¹⁴ | 32 | 100.0 | 0.35 | Good |
| Yb ₂ O ₃ | 0.01 | 1.0 | 182 | > 10 ¹⁴ | 32 | 99.8 | 0.31 | Good |
| | 0.10 | 1.0 | 183 | > 10 ¹⁴ | 34 | 99.9 | 0.31 | Good |
| | 1.00 | 1.0 | 194 | > 10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| | 2.00 | 1.0 | 201 | > 10 ¹⁴ | 36 | 100.0 | 0.36 | Good |
| | 5.00 | 1.0 | 202 | > 10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| CeO ₂ La ₂ O ₃ | 0.80 0.90 | 1.0 | 230 | > 10 ¹⁴ | 34 | 100.0 | 0.36 | Good |
| La ₂ O ₃ Dy ₂ O ₃ | 0.50 1.00 | 1.0 | 231 | > 10 ¹⁴ | 37 | 100.0 | 0.37 | Good |
| Yb ₂ O ₃ Nd ₂ O ₃ | 0.50 0.50 | 1.0 | 233 | > 10 ¹⁴ | 35 | 100.0 | 0.37 | Good |
| CeO ₂ La ₂ O ₃ Nd ₂ O ₃ | 0.50 0.50 0.50 | 1.0 | 240 | > 10 ¹⁴ | 36 | 100.0 | 0.38 | Good |

Table 4

| No. | Y ₂ O ₃ parts by weight | B parts by weight | Additive | | Thermal conductiv- ity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|-------------------------|--|----------------------|--------------------------------------|---------------------------------|--------------------------------|--------------------------|------------------------------------|------------|
| | | | | parts by weight | | | | | | |
| 1 | 2.0 | 0.50 | Li ₂ O | 0.50 | 182 | >10 ¹⁴ | 35 | 100.0 | 0.31 | Good |
| 2 | 2.0 | 0.50 | Li ₂ O | 1.00 | 194 | >10 ¹⁴ | 34 | 100.0 | 0.30 | Good |
| 3 | 2.0 | 0.50 | Na ₂ O | 0.50 | 183 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 4 | 2.0 | 0.50 | Na ₂ O | 1.00 | 190 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 5 | 2.0 | 0.50 | K ₂ O | 0.50 | 175 | >10 ¹⁴ | 35 | 100.0 | 0.31 | Good |
| 6 | 2.0 | 0.50 | K ₂ O | 1.00 | 178 | >10 ¹⁴ | 38 | 100.0 | 0.33 | Good |
| 7 | 2.0 | 0.50 | B ₂ O ₃ | 0.50 | 202 | >10 ¹⁴ | 38 | 100.0 | 0.31 | Good |
| 8 | 2.0 | 0.50 | B ₂ O ₃ | 1.00 | 205 | >10 ¹⁴ | 36 | 100.0 | 0.30 | Good |
| 9 | 2.0 | 0.50 | SiO ₂ | 0.50 | 178 | >10 ¹⁴ | 37 | 100.0 | 0.33 | Good |
| 10 | 2.0 | 0.50 | SiO ₂ | 1.00 | 177 | >10 ¹⁴ | 32 | 100.0 | 0.29 | Good |
| 11 | 2.0 | 0.50 | GeO ₂ | 0.50 | 181 | >10 ¹⁴ | 40 | 100.0 | 0.32 | Good |
| 12 | 2.0 | 0.50 | GeO ₂ | 1.00 | 189 | >10 ¹⁴ | 31 | 100.0 | 0.34 | Good |
| 13 | 2.0 | 0.50 | As ₂ O ₃ | 0.50 | 190 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 14 | 2.0 | 0.50 | As ₂ O ₃ | 1.00 | 192 | >10 ¹⁴ | 37 | 100.0 | 0.31 | Good |
| 15 | 2.0 | 0.50 | P ₂ O ₅ | 0.50 | 193 | >10 ¹⁴ | 35 | 100.0 | 0.30 | Good |
| 16 | 2.0 | 0.50 | P ₂ O ₅ | 1.00 | 195 | >10 ¹⁴ | 31 | 100.0 | 0.29 | Good |
| 17 | 2.0 | 1.00 | Li ₂ O | 0.50 | 205 | >10 ¹⁴ | 39 | 100.0 | 0.34 | Good |
| 18 | 2.0 | 1.00 | Li ₂ O | 1.00 | 210 | >10 ¹⁴ | 31 | 100.0 | 0.33 | Good |
| 19 | 2.0 | 1.00 | Na ₂ O | 0.50 | 201 | >10 ¹⁴ | 31 | 100.0 | 0.35 | Good |
| 20 | 2.0 | 1.00 | Na ₂ O | 1.00 | 198 | >10 ¹⁴ | 32 | 100.0 | 0.34 | Good |
| 21 | 2.0 | 1.00 | K ₂ O | 0.50 | 205 | >10 ¹⁴ | 37 | 100.0 | 0.36 | Good |
| 22 | 2.0 | 1.00 | K ₂ O | 1.00 | 210 | >10 ¹⁴ | 36 | 100.0 | 0.36 | Good |
| 23 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | 223 | >10 ¹⁴ | 32 | 100.0 | 0.38 | Good |
| 24 | 2.0 | 1.00 | B ₂ O ₃ | 1.00 | 228 | >10 ¹⁴ | 33 | 100.0 | 0.38 | Good |
| 25 | 2.0 | 1.00 | SiO ₂ | 0.50 | 201 | >10 ¹⁴ | 31 | 100.0 | 0.37 | Good |
| 26 | 2.0 | 1.00 | SiO ₂ | 1.00 | 204 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 27 | 2.0 | 1.00 | GeO ₂ | 0.50 | 204 | >10 ¹⁴ | 30 | 100.0 | 0.34 | Good |
| 28 | 2.0 | 1.00 | GeO ₂ | 1.00 | 209 | >10 ¹⁴ | 37 | 100.0 | 0.36 | Good |
| 29 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | 198 | >10 ¹⁴ | 37 | 100.0 | 0.39 | Good |
| 30 | 2.0 | 1.00 | As ₂ O ₃ | 1.00 | 194 | >10 ¹⁴ | 36 | 100.0 | 0.38 | Good |
| 31 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | 213 | >10 ¹⁴ | 34 | 100.0 | 0.37 | Good |
| 32 | 2.0 | 1.00 | P ₂ O ₅ | 1.00 | 217 | >10 ¹⁴ | 32 | 100.0 | 0.37 | Good |
| 33 | 2.0 | 1.00 | Li ₂ O B ₂ O ₃ | 0.70 0.70 | 220 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 34 | 2.0 | 1.00 | Li ₂ O P ₂ O ₅ | 0.50 1.00 | 221 | >10 ¹⁴ | 38 | 100.0 | 0.32 | Good |
| 35 | 2.0 | 1.00 | K ₂ O GeO ₂ | 0.50 1.00 | 221 | >10 ¹⁴ | 36 | 100.0 | 0.34 | Good |
| 36 | 2.0 | 1.00 1.00 1.00 | K ₂ O P ₂ O ₅ B ₂ O ₃ | 0.50 0.80 0.80 | 229 | >10 ¹⁴ | 34 | 100.0 | 0.29 | Good |

Table 5

| No. | Y ₂ O ₃ parts by weight | B parts by weight | Additive | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|-------------------------|---|----------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|------------------------------------|------------|
| | | | | parts by weight | | | | | | |
| 1 | 2.0 | 0.50 | LaB ₆ | 0.50 | 223 | >10 ¹⁴ | 33 | 100.0 | 0.29 | Good |
| 2 | 2.0 | 0.50 | LaB ₆ | 1.00 | 235 | >10 ¹⁴ | 34 | 100.0 | 0.31 | Good |
| 3 | 2.0 | 0.50 | CaB ₆ | 0.50 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.30 | Good |
| 4 | 2.0 | 0.50 | CaB ₆ | 1.00 | 221 | >10 ¹⁴ | 35 | 100.0 | 0.31 | Good |
| 5 | 2.0 | 0.50 | Ca ₃ N ₂ | 0.50 | 234 | >10 ¹⁴ | 34 | 100.0 | 0.29 | Good |
| 6 | 2.0 | 0.50 | Ca ₃ N ₂ | 1.00 | 240 | >10 ¹⁴ | 37 | 100.0 | 0.30 | Good |
| 7 | 2.0 | 0.50 | AlP | 0.50 | 204 | >10 ¹⁴ | 37 | 100.0 | 0.31 | Good |
| 8 | 2.0 | 0.50 | AlP | 1.00 | 207 | >10 ¹⁴ | 38 | 100.0 | 0.32 | Good |
| 9 | 2.0 | 0.50 | LiMgP | 0.50 | 203 | >10 ¹⁴ | 36 | 100.0 | 0.30 | Good |
| 10 | 2.0 | 0.50 | LiMgP | 1.00 | 206 | >10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| 11 | 2.0 | 0.50 | CaS | 0.50 | 209 | >10 ¹⁴ | 37 | 100.0 | 0.32 | Good |
| 12 | 2.0 | 0.50 | CaS | 1.00 | 211 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 13 | 2.0 | 0.50 | BaS | 0.50 | 218 | >10 ¹⁴ | 39 | 100.0 | 0.34 | Good |
| 14 | 2.0 | 0.50 | BaS | 1.00 | 214 | >10 ¹⁴ | 32 | 100.0 | 0.33 | Good |
| 15 | 2.0 | 0.50 | MoSi ₂ | 0.50 | 195 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 16 | 2.0 | 0.50 | MoSi ₂ | 1.00 | 201 | >10 ¹⁴ | 32 | 100.0 | 0.31 | Good |
| 17 | 2.0 | 0.50 | CaH ₂ | 0.50 | 234 | >10 ¹⁴ | 40 | 100.0 | 0.30 | Good |
| 18 | 2.0 | 0.50 | CaH ₂ | 1.00 | 236 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 19 | 2.0 | 0.50 | LiAlH ₄ | 0.50 | 230 | >10 ¹⁴ | 32 | 100.0 | 0.35 | Good |
| 20 | 2.0 | 0.50 | LiAlH ₄ | 1.00 | 239 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 21 | 2.0 | 1.00 | LaB ₆ | 0.50 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.36 | Good |
| 22 | 2.0 | 1.00 | CaB ₆ | 0.50 | 222 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 23 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | 238 | >10 ¹⁴ | 39 | 100.0 | 0.36 | Good |
| 24 | 2.0 | 1.00 | AlP | 0.50 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.36 | Good |
| 25 | 2.0 | 1.00 | LiMgP | 0.50 | 211 | >10 ¹⁴ | 37 | 100.0 | 0.35 | Good |
| 26 | 2.0 | 1.00 | CaS | 0.50 | 212 | >10 ¹⁴ | 36 | 100.0 | 0.38 | Good |
| 27 | 2.0 | 1.00 | BaS | 0.50 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.37 | Good |
| 28 | 2.0 | 1.00 | MoSi ₂ | 0.50 | 196 | >10 ¹⁴ | 36 | 100.0 | 0.38 | Good |
| 29 | 2.0 | 1.00 | MoSi ₂ | 1.00 | 203 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 30 | 2.0 | 1.00 | CaH ₂ | 0.50 | 240 | >10 ¹⁴ | 35 | 100.0 | 0.38 | Good |
| 31 | 2.0 | 1.00 | CaH ₂ | 1.00 | 245 | >10 ¹⁴ | 37 | 100.0 | 0.35 | Good |
| 32 | 2.0 | 1.00 | LiAlH ₄ | 0.50 | 236 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 33 | 2.0 | 1.00 | LiAlH ₄ | 1.00 | 244 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 34 | 2.0 | 1.00 | LiAlH ₄ LaB ₆ | 0.50 0.50 | 246 | >10 ¹⁴ | 33 | 100.0 | 0.28 | Good |
| 35 | 2.0 | 1.00 | CaB ₆ LaB ₆ | 0.50 0.50 | 241 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 36 | 2.0 | 1.00 | Ca ₃ N ₂ CaS | 1.00 0.50 | 239 | >10 ¹⁴ | 36 | 100.0 | 0.38 | Good |
| 37 | 2.0 | 1.00 | CaS CaH ₂ CaB ₆ | 0.50 0.50 0.50 | 244 | >10 ¹⁴ | 35 | 100.0 | 0.36 | Good |

Table 6-1

| No. | Y ₂ O ₃ parts by weight | B parts by weight | Additive | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|-------------------------|--------------------------------|--------------------|--------------------------------|--------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|------------------------------------|------------|
| | | | | parts by weight | | parts by weight | | | | | | |
| 1 | 2.0 | 1.00 | LaB ₆ | 0.50 | Li ₂ O | 0.20 | 226 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 2 | 2.0 | 1.00 | LaB ₆ | 0.50 | K ₂ O | 0.10 | 227 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 3 | 2.0 | 1.00 | LaB ₆ | 0.50 | B ₂ O ₃ | 0.50 | 219 | >10 ¹⁴ | 36 | 100.0 | 0.31 | Good |
| 4 | 2.0 | 1.00 | LaB ₆ | 0.50 | SiO ₂ | 0.30 | 220 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 5 | 2.0 | 1.00 | LaB ₆ | 0.50 | GeO ₂ | 0.10 | 223 | >10 ¹⁴ | 40 | 100.0 | 0.30 | Good |
| 6 | 2.0 | 1.00 | LaB ₆ | 0.50 | P ₂ O ₅ | 0.20 | 231 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 7 | 2.0 | 1.00 | LaB ₆ | 1.00 | As ₂ O ₃ | 0.10 | 233 | >10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| 8 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | Li ₂ O | 0.20 | 232 | >10 ¹⁴ | 33 | 100.0 | 0.23 | Good |
| 9 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | K ₂ O | 0.10 | 231 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 10 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | B ₂ O ₃ | 0.50 | 228 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 11 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | SiO ₂ | 0.30 | 232 | >10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| 12 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | GeO ₂ | 0.10 | 229 | >10 ¹⁴ | 36 | 100.0 | 0.31 | Good |
| 13 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | P ₂ O ₅ | 0.20 | 219 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 14 | 2.0 | 1.00 | Ca ₃ N ₂ | 1.00 | As ₂ O ₃ | 0.10 | 223 | >10 ¹⁴ | 34 | 100.0 | 0.23 | Good |
| 15 | 2.0 | 1.00 | CaS | 0.50 | Li ₂ O | 0.20 | 224 | >10 ¹⁴ | 31 | 100.0 | 0.31 | Good |
| 16 | 2.0 | 1.00 | CaS | 0.50 | K ₂ O | 0.10 | 221 | >10 ¹⁴ | 32 | 100.0 | 0.33 | Good |
| 17 | 2.0 | 1.00 | CaS | 0.50 | B ₂ O ₃ | 0.50 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.35 | Good |
| 18 | 2.0 | 1.00 | CaS | 0.50 | SiO ₂ | 0.30 | 219 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 19 | 2.0 | 1.00 | CaS | 0.50 | GeO ₂ | 0.10 | 219 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 20 | 2.0 | 1.00 | CaS | 0.50 | P ₂ O ₅ | 0.20 | 218 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 21 | 2.0 | 1.00 | CaS | 0.50 | As ₂ O ₃ | 0.10 | 221 | >10 ¹⁴ | 32 | 100.0 | 0.33 | Good |
| 22 | 2.0 | 1.00 | MoSi ₂ | 0.50 | Li ₂ O | 0.20 | 204 | >10 ¹⁴ | 36 | 100.0 | 0.34 | Good |
| 23 | 2.0 | 1.00 | MoSi ₂ | 0.50 | K ₂ O | 0.10 | 207 | >10 ¹⁴ | 31 | 100.0 | 0.34 | Good |
| 24 | 2.0 | 1.00 | MoSi ₂ | 0.50 | B ₂ O ₃ | 0.50 | 201 | >10 ¹⁴ | 41 | 100.0 | 0.33 | Good |
| 25 | 2.0 | 1.00 | MoSi ₂ | 0.50 | SiO ₂ | 0.30 | 203 | >10 ¹⁴ | 40 | 100.0 | 0.32 | Good |
| 26 | 2.0 | 1.00 | MoSi ₂ | 0.50 | GeO ₂ | 0.10 | 203 | >10 ¹⁴ | 39 | 100.0 | 0.37 | Good |
| 27 | 2.0 | 1.00 | MoSi ₂ | 0.50 | P ₂ O ₅ | 0.20 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.35 | Good |
| 28 | 2.0 | 1.00 | MoSi ₂ | 1.00 | As ₂ O ₃ | 0.10 | 207 | >10 ¹⁴ | 32 | 100.0 | 0.34 | Good |

Table 6-2

| No. | Y ₂ O ₃ parts by weight | B parts by weight | Additive | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|-------------------------|---|----------------------|--|----------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|------------------------------------|------------|
| | | | | parts by weight | | parts by weight | | | | | | |
| 29 | 2.0 | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 0.20 | 233 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 30 | 2.0 | 1.00 | CaH ₂ | 0.50 | K ₂ O | 0.10 | 231 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 31 | 2.0 | 1.00 | CaH ₂ | 0.50 | B ₂ O ₃ | 0.50 | 239 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 32 | 2.0 | 1.00 | CaH ₂ | 0.50 | SiO ₂ | 0.30 | 220 | >10 ¹⁴ | 35 | 100.0 | 0.35 | Good |
| 33 | 2.0 | 1.00 | CaH ₂ | 0.50 | GeO ₂ | 0.10 | 232 | >10 ¹⁴ | 39 | 100.0 | 0.31 | Good |
| 34 | 2.0 | 1.00 | CaH ₂ | 0.50 | P ₂ O ₅ | 0.20 | 233 | >10 ¹⁴ | 31 | 100.0 | 0.35 | Good |
| 35 | 2.0 | 1.00 | CaH ₂ | 1.00 | As ₂ O ₃ | 0.10 | 230 | >10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| 36 | 2.0 | 1.00 | LaB ₆ CaH ₂ | 0.20 0.30 | B ₂ O ₃ | 0.20 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.36 | Good |
| 37 | 2.0 | 1.00 | LaB ₆ | 0.50 | B ₂ O ₃ Li ₂ O | 0.20 0.30 | 242 | >10 ¹⁴ | 36 | 100.0 | 0.39 | Good |
| 38 | 2.0 | 1.00 | CaS CaH ₂ | 0.20 0.30 | B ₂ O ₃ P ₂ O ₅ | 0.20 0.20 | 239 | >10 ¹⁴ | 37 | 100.0 | 0.39 | Good |
| 39 | 2.0 | 1.00 | CaS CaH ₂ | 0.20 0.30 | B ₂ O ₃ P ₂ O ₅ | 0.20 0.20 | 243 | >10 ¹⁴ | 40 | 100.0 | 0.38 | Good |
| 40 | 2.0 | 1.00 | CaS CaH ₂ Ca ₃ N ₂ | 0.20 0.20 0.10 | B ₂ O ₃ SiO ₂ Na ₂ O | 0.20 0.20 1.00 | 245 | >10 ¹⁴ | 37 | 100.0 | 0.34 | Good |

Table 7

| No. | Y ₂ O ₃ parts by weight | B parts by weight | Additive | | Thermal conductiv- ity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|-------------------------|---|----------------------|--------------------------------------|---------------------------------|--------------------------------|--------------------------|------------------------------------|------------|
| | | | | parts by weight | | | | | | |
| 1 | 2.0 | 0.50 | Al ₂ O ₃ | 0.50 | 202 | >10 ¹⁴ | 35 | 100.0 | 0.30 | Good |
| 2 | 2.0 | 0.50 | Al ₂ O ₃ | 1.00 | 206 | >10 ¹⁴ | 33 | 100.0 | 0.31 | Good |
| 3 | 2.0 | 0.50 | Ga ₂ O ₃ | 0.50 | 203 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 4 | 2.0 | 0.50 | Ga ₂ O ₃ | 1.00 | 206 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 5 | 2.0 | 0.50 | In ₂ O ₃ | 0.50 | 211 | >10 ¹⁴ | 37 | 100.0 | 0.31 | Good |
| 6 | 2.0 | 0.50 | In ₂ O ₃ | 1.00 | 206 | >10 ¹⁴ | 33 | 100.0 | 0.29 | Good |
| 7 | 2.0 | 0.50 | WO ₃ | 0.50 | 202 | >10 ¹⁴ | 35 | 100.0 | 0.28 | Good |
| 8 | 2.0 | 0.50 | WO ₃ | 1.00 | 206 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 9 | 2.0 | 0.50 | Bi ₂ O ₃ | 0.50 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.29 | Good |
| 10 | 2.0 | 0.50 | Bi ₂ O ₃ | 1.00 | 208 | >10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| 11 | 2.0 | 0.50 | PbO | 0.50 | 202 | >10 ¹⁴ | 33 | 100.0 | 0.31 | Good |
| 12 | 2.0 | 0.50 | PbO | 1.00 | 203 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 13 | 2.0 | 0.50 | Sb ₂ O ₃ | 0.50 | 210 | >10 ¹⁴ | 37 | 100.0 | 0.33 | Good |
| 14 | 2.0 | 0.50 | Sb ₂ O ₃ | 1.00 | 212 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 15 | 2.0 | 0.50 | CdO | 0.50 | 216 | >10 ¹⁴ | 35 | 100.0 | 0.31 | Good |
| 16 | 2.0 | 0.50 | CdO | 1.00 | 211 | >10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| 17 | 2.0 | 0.50 | ZnO | 0.50 | 207 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 18 | 2.0 | 0.50 | ZnO | 1.00 | 209 | >10 ¹⁴ | 32 | 100.0 | 0.35 | Good |
| 19 | 2.0 | 1.00 | Al ₂ O ₃ | 0.50 | 232 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 20 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.36 | Good |
| 21 | 2.0 | 1.00 | Ga ₂ O ₃ | 0.50 | 221 | >10 ¹⁴ | 36 | 100.0 | 0.36 | Good |
| 22 | 2.0 | 1.00 | Ga ₂ O ₃ | 1.00 | 223 | >10 ¹⁴ | 34 | 100.0 | 0.37 | Good |
| 23 | 2.0 | 1.00 | In ₂ O ₃ | 0.50 | 233 | >10 ¹⁴ | 37 | 100.0 | 0.36 | Good |
| 24 | 2.0 | 1.00 | In ₂ O ₃ | 1.00 | 221 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 25 | 2.0 | 1.00 | WO ₃ | 0.50 | 240 | >10 ¹⁴ | 31 | 100.0 | 0.36 | Good |
| 26 | 2.0 | 1.00 | WO ₃ | 1.00 | 222 | >10 ¹⁴ | 38 | 100.0 | 0.37 | Good |
| 27 | 2.0 | 1.00 | Bi ₂ O ₃ | 0.50 | 231 | >10 ¹⁴ | 37 | 100.0 | 0.36 | Good |
| 28 | 2.0 | 1.00 | Bi ₂ O ₃ | 1.00 | 232 | >10 ¹⁴ | 33 | 100.0 | 0.35 | Good |
| 29 | 2.0 | 1.00 | PbO | 0.50 | 237 | >10 ¹⁴ | 36 | 100.0 | 0.38 | Good |
| 30 | 2.0 | 1.00 | PbO | 1.00 | 236 | >10 ¹⁴ | 35 | 100.0 | 0.40 | Good |
| 31 | 2.0 | 1.00 | Sb ₂ O ₃ | 0.50 | 238 | >10 ¹⁴ | 31 | 100.0 | 0.36 | Good |
| 32 | 2.0 | 1.00 | Sb ₂ O ₃ | 1.00 | 233 | >10 ¹⁴ | 32 | 100.0 | 0.36 | Good |
| 33 | 2.0 | 1.00 | CdO | 0.50 | 232 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 34 | 2.0 | 1.00 | CdO | 1.00 | 222 | >10 ¹⁴ | 34 | 100.0 | 0.35 | Good |
| 35 | 2.0 | 1.00 | ZnO | 0.50 | 213 | >10 ¹⁴ | 35 | 100.0 | 0.37 | Good |
| 36 | 2.0 | 1.00 | ZnO | 1.00 | 215 | >10 ¹⁴ | 32 | 100.0 | 0.38 | Good |
| 37 | 2.0 | 1.00 | Al ₂ O ₃ In ₂ O ₃ | 0.50 0.50 | 237 | >10 ¹⁴ | 39 | 100.0 | 0.35 | Good |
| 38 | 2.0 | 1.00 | Al ₂ O ₃ WO ₃ | 0.60 0.60 | 238 | >10 ¹⁴ | 37 | 100.0 | 0.34 | Good |
| 39 | 2.0 | 1.00 | CdO Sb ₂ O ₃ | 0.30 0.30 | 240 | >10 ¹⁴ | 34 | 100.0 | 0.37 | Good |
| 40 | 2.0 | 1.00 | Al ₂ O ₃ In ₂ O ₃ PbO | 0.30 0.20 0.50 | 232 | >10 ¹⁴ | 35 | 100.0 | 0.35 | Good |

Table 8-1

| No. | Y ₂ O ₃ parts by weight | Zn parts by weight | Additive | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance | |
|-----|---|--------------------------|-------------------------------|------|--------------------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|------|
| | | | parts by weight | | parts by weight | | | | | | | |
| 1 | 2.0 | 1.00 | Li ₂ O | 0.50 | Al ₂ O ₃ | 0.20 | 213 | >10 ¹⁴ | 32 | 100.0 | 0.31 | Good |
| 2 | 2.0 | 1.00 | Li ₂ O | 0.50 | Ga ₂ O ₃ | 0.10 | 221 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 3 | 2.0 | 1.00 | Li ₂ O | 0.50 | In ₂ O ₃ | 0.60 | 223 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 4 | 2.0 | 1.00 | Li ₂ O | 0.50 | WO ₃ | 0.30 | 221 | >10 ¹⁴ | 34 | 100.0 | 0.31 | Good |
| 5 | 2.0 | 1.00 | Li ₂ O | 0.50 | Bi ₂ O ₃ | 0.10 | 219 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 6 | 2.0 | 1.00 | Li ₂ O | 0.50 | PbO | 0.20 | 223 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 7 | 2.0 | 1.00 | Li ₂ O | 1.00 | Sb ₂ O ₃ | 0.10 | 224 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 8 | 2.0 | 1.00 | Li ₂ O | 1.00 | CdO | 0.30 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.35 | Good |
| 9 | 2.0 | 1.00 | Li ₂ O | 1.00 | ZnO | 0.30 | 214 | >10 ¹⁴ | 33 | 100.0 | 0.37 | Good |
| 10 | 2.0 | 1.00 | Na ₂ O | 0.50 | Al ₂ O ₃ | 0.20 | 223 | >10 ¹⁴ | 32 | 100.0 | 0.33 | Good |
| 11 | 2.0 | 1.00 | Na ₂ O | 0.50 | Ga ₂ O ₃ | 0.10 | 220 | >10 ¹⁴ | 34 | 100.0 | 0.31 | Good |
| 12 | 2.0 | 1.00 | Na ₂ O | 0.50 | In ₂ O ₃ | 0.50 | 219 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 13 | 2.0 | 1.00 | Na ₂ O | 0.50 | WO ₃ | 0.30 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 14 | 2.0 | 1.00 | Na ₂ O | 0.50 | Bi ₂ O ₃ | 0.10 | 225 | >10 ¹⁴ | 34 | 100.0 | 2.33 | Good |
| 15 | 2.0 | 1.00 | Na ₂ O | 0.50 | PbO | 0.20 | 210 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 16 | 2.0 | 1.00 | Na ₂ O | 1.00 | Sb ₂ O ₃ | 0.10 | 223 | >10 ¹⁴ | 35 | 100.0 | 0.31 | Good |
| 17 | 2.0 | 1.00 | Na ₂ O | 0.50 | CdO | 0.30 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 18 | 2.0 | 1.00 | Na ₂ O | 1.00 | ZnO | 0.30 | 217 | >10 ¹⁴ | 33 | 100.0 | 0.29 | Good |
| 19 | 2.0 | 1.00 | K ₂ O | 0.50 | Al ₂ O ₃ | 0.20 | 221 | >10 ¹⁴ | 33 | 100.0 | 0.30 | Good |
| 20 | 2.0 | 1.00 | K ₂ O | 0.50 | Ga ₂ O ₃ | 0.10 | 214 | >10 ¹⁴ | 31 | 100.0 | 0.31 | Good |
| 21 | 2.0 | 1.00 | K ₂ O | 0.50 | In ₂ O ₃ | 0.50 | 220 | >10 ¹⁴ | 35 | 100.0 | 0.32 | Good |
| 22 | 2.0 | 1.00 | K ₂ O | 0.50 | WO ₃ | 0.30 | 210 | >10 ¹⁴ | 33 | 100.0 | 0.38 | Good |
| 23 | 2.0 | 1.00 | K ₂ O | 0.50 | Bi ₂ O ₃ | 0.10 | 212 | >10 ¹⁴ | 32 | 100.0 | 0.37 | Good |
| 24 | 2.0 | 1.00 | K ₂ O | 0.50 | PbO | 0.20 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 25 | 2.0 | 1.00 | K ₂ O | 1.00 | Sb ₂ O ₃ | 0.10 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 26 | 2.0 | 1.00 | K ₂ O | 0.50 | CdO | 0.30 | 217 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 27 | 2.0 | 1.00 | K ₂ O | 1.00 | ZnO | 0.30 | 222 | >10 ¹⁴ | 34 | 100.0 | 0.38 | Good |
| 28 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | Al ₂ O ₃ | 0.20 | 201 | >10 ¹⁴ | 34 | 100.0 | 0.40 | Good |
| 29 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | Ga ₂ O ₃ | 0.10 | 203 | >10 ¹⁴ | 33 | 100.0 | 0.42 | Good |

Table 8-2

| No. | Y ₂ O ₃ parts by weight | Zn parts by weight | Additive | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance | |
|-----|---|--------------------------|--------------------------------|--------------------|--------------------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|------|
| | | | | parts by weight | parts by weight | | | | | | | |
| 30 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | In ₂ O ₃ | 0.50 | 202 | >10 ¹⁴ | 38 | 100.0 | 0.40 | Good |
| 31 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | WO ₃ | 0.30 | 203 | >10 ¹⁴ | 32 | 100.0 | 0.39 | Good |
| 32 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | Bi ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 31 | 100.0 | 0.38 | Good |
| 33 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | PbO | 0.20 | 204 | >10 ¹⁴ | 32 | 100.0 | 0.37 | Good |
| 34 | 2.0 | 1.00 | B ₂ O ₃ | 1.00 | Sb ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 33 | 100.0 | 0.36 | Good |
| 35 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | CdO | 0.30 | 203 | >10 ¹⁴ | 33 | 100.0 | 0.38 | Good |
| 36 | 2.0 | 1.00 | B ₂ O ₃ | 1.00 | ZnO | 0.30 | 204 | >10 ¹⁴ | 32 | 100.0 | 0.35 | Good |
| 37 | 2.0 | 1.00 | SiO ₂ | 0.50 | Al ₂ O ₃ | 0.20 | 240 | >10 ¹⁴ | 31 | 100.0 | 0.32 | Good |
| 38 | 2.0 | 1.00 | SiO ₂ | 0.50 | Ga ₂ O ₃ | 0.10 | 238 | >10 ¹⁴ | 32 | 100.0 | 0.31 | Good |
| 39 | 2.0 | 1.00 | SiO ₂ | 0.50 | In ₂ O ₃ | 0.50 | 239 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 40 | 2.0 | 1.00 | SiO ₂ | 0.50 | WO ₃ | 0.30 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.30 | Good |
| 41 | 2.0 | 1.00 | SiO ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 38 | 100.0 | 0.29 | Good |
| 42 | 2.0 | 1.00 | SiO ₂ | 0.50 | PbO | 0.20 | 231 | >10 ¹⁴ | 33 | 100.0 | 0.29 | Good |
| 43 | 2.0 | 1.00 | SiO ₂ | 1.00 | Sb ₂ O ₃ | 0.10 | 238 | >10 ¹⁴ | 34 | 100.0 | 0.30 | Good |
| 44 | 2.0 | 1.00 | SiO ₂ | 0.50 | CdO | 0.30 | 237 | >10 ¹⁴ | 33 | 100.0 | 0.31 | Good |
| 45 | 2.0 | 1.00 | SiO ₂ | 1.00 | ZnO | 0.30 | 233 | >10 ¹⁴ | 32 | 100.0 | 0.32 | Good |
| 46 | 2.0 | 1.00 | GeO ₂ | 0.50 | Al ₂ O ₃ | 0.20 | 221 | >10 ¹⁴ | 32 | 100.0 | 0.29 | Good |
| 47 | 2.0 | 1.00 | GeO ₂ | 0.50 | Ga ₂ O ₃ | 0.10 | 223 | >10 ¹⁴ | 31 | 100.0 | 0.30 | Good |
| 48 | 2.0 | 1.00 | GeO ₂ | 0.50 | In ₂ O ₃ | 0.50 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.29 | Good |
| 49 | 2.0 | 1.00 | GeO ₂ | 0.50 | WO ₃ | 0.30 | 219 | >10 ¹⁴ | 33 | 100.0 | 0.31 | Good |
| 50 | 2.0 | 1.00 | GeO ₂ | 0.60 | Bi ₂ O ₃ | 0.10 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.31 | Good |
| 51 | 2.0 | 1.00 | GeO ₂ | 0.50 | PbO | 0.20 | 219 | >10 ¹⁴ | 37 | 100.0 | 0.32 | Good |
| 52 | 2.0 | 1.00 | GeO ₂ | 1.00 | Sb ₂ O ₃ | 0.10 | 209 | >10 ¹⁴ | 38 | 100.0 | 0.31 | Good |
| 53 | 2.0 | 1.00 | GeO ₂ | 0.50 | CdO | 0.30 | 212 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 54 | 2.0 | 1.00 | GeO ₂ | 1.00 | ZnO | 0.30 | 221 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 55 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | Al ₂ O ₃ | 0.20 | 241 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 56 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | Ga ₂ O ₃ | 0.10 | 239 | >10 ¹⁴ | 31 | 100.0 | 0.30 | Good |
| 57 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | In ₂ O ₃ | 0.50 | 237 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 58 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | WO ₃ | 0.30 | 239 | >10 ¹⁴ | 34 | 100.0 | 2.32 | Good |

Table 8-3

| No. | Y ₂ O ₃ parts by weight | Zn parts by weight | Additive | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|--------------------------|-------------------------------------|--------------------|-------------------------------------|--------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|
| | | | | parts by weight | | parts by weight | | | | | | |
| 59 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | Bi ₂ O ₃ | 0.10 | 237 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 60 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | PbO | 0.20 | 233 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 61 | 2.0 | 1.00 | As ₂ O ₃ | 1.00 | Sb ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 32 | 100.0 | 0.31 | Good |
| 62 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | CdO | 0.30 | 238 | >10 ¹⁴ | 35 | 100.0 | 0.32 | Good |
| 63 | 2.0 | 1.00 | As ₂ O ₃ | 1.00 | ZnO | 0.30 | 234 | >10 ¹⁴ | 31 | 100.0 | 0.32 | Good |
| 64 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | As ₂ O ₃ | 0.20 | 239 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 65 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | Ga ₂ O ₃ | 0.10 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.35 | Good |
| 66 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | In ₂ O ₃ | 0.50 | 234 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 67 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | WO ₃ | 0.30 | 239 | >10 ¹⁴ | 39 | 100.0 | 0.32 | Good |
| 68 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | Bi ₂ O ₃ | 0.10 | 234 | >10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| 69 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | PbO | 0.20 | 234 | >10 ¹⁴ | 33 | 100.0 | 0.29 | Good |
| 70 | 2.0 | 1.00 | P ₂ O ₅ | 1.00 | Sb ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 32 | 100.0 | 0.29 | Good |
| 71 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | CdO | 0.30 | 238 | >10 ¹⁴ | 31 | 100.0 | 0.32 | Good |
| 72 | 2.0 | 1.00 | P ₂ O ₅ | 1.00 | ZnO | 0.30 | 237 | >10 ¹⁴ | 30 | 100.0 | 0.34 | Good |
| 73 | 2.0 | 1.00 | Li ₂ O | 0.20 | As ₂ O ₃ | 0.20 | 238 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| | | | + B ₂ O ₃ | 0.30 | | | | | | | | |
| 74 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | As ₂ O ₃ | 0.20 | 237 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| | | | | | + In ₂ O ₃ | 0.30 | | | | | | |
| 75 | 2.0 | 1.00 | Na ₂ O | 0.10 | WO ₃ | 0.20 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.35 | Good |
| | | | + SiO ₂ | 0.30 | + Sb ₂ O ₃ | 0.20 | | | | | | |
| 76 | 2.0 | 1.00 | Li ₂ O | 0.02 | CdO | 0.20 | 241 | >10 ¹⁴ | 38 | 100.0 | 0.36 | Good |
| | | | + P ₂ O ₅ | 0.30 | + ZnO | 0.20 | | | | | | |
| 76 | 2.0 | 1.00 | K ₂ O | 0.01 | As ₂ O ₃ | 0.20 | 242 | >10 ¹⁴ | 35 | 100.0 | 0.37 | Good |
| | | | + As ₂ O ₃ | 0.01 | + CdO | 0.20 | | | | | | |
| | | | + SiO ₂ | | + PbO | | | | | | | |
| | | | | 0.05 | | 1.00 | | | | | | |

Table 9-1

| No. | Y ₂ O ₃ parts by weight | Li parts by weight | Additive | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|--------------------------|--------------------------------|--------------------|--------------------------------|--------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|
| | | | | parts by weight | | parts by weight | | | | | | |
| 1 | 2.0 | 1.00 | CaH ₂ | 0.50 | As ₂ O ₃ | 0.20 | 221 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |
| 2 | 2.0 | 1.00 | CaH ₂ | 0.50 | Ga ₂ O ₃ | 0.20 | 222 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 3 | 2.0 | 1.00 | CaH ₂ | 0.50 | In ₂ O ₃ | 0.20 | 219 | >10 ¹⁴ | 35 | 100.0 | 0.35 | Good |
| 4 | 2.0 | 1.00 | CaH ₂ | 0.50 | WO ₃ | 0.20 | 223 | >10 ¹⁴ | 38 | 100.0 | 0.36 | Good |
| 5 | 2.0 | 1.00 | CaH ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 228 | >10 ¹⁴ | 40 | 100.0 | 0.34 | Good |
| 6 | 2.0 | 1.00 | CaH ₂ | 0.50 | PbO | 0.10 | 220 | >10 ¹⁴ | 33 | 100.0 | 0.40 | Good |
| 7 | 2.0 | 1.00 | CaH ₂ | 0.50 | Sb ₂ O ₃ | 0.10 | 221 | >10 ¹⁴ | 37 | 100.0 | 0.37 | Good |
| 8 | 2.0 | 1.00 | CaH ₂ | 0.50 | CdO | 0.30 | 218 | >10 ¹⁴ | 39 | 100.0 | 0.36 | Good |
| 9 | 2.0 | 1.00 | CaH ₂ | 0.50 | ZnO | 0.30 | 232 | >10 ¹⁴ | 39 | 100.0 | 0.34 | Good |
| 10 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | As ₂ O ₃ | 0.20 | 238 | >10 ¹⁴ | 32 | 100.0 | 0.35 | Good |
| 11 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | In ₂ O ₃ | 0.20 | 232 | >10 ¹⁴ | 34 | 100.0 | 0.31 | Good |
| 12 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | WO ₃ | 0.20 | 235 | >10 ¹⁴ | 35 | 100.0 | 0.39 | Good |
| 13 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 230 | >10 ¹⁴ | 33 | 100.0 | 0.29 | Good |
| 14 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | PbO | 0.10 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.30 | Good |
| 15 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | Sb ₂ O ₃ | 0.10 | 230 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 16 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | CdO | 0.30 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.35 | Good |
| 17 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | ZnO | 0.30 | 209 | >10 ¹⁴ | 33 | 100.0 | 0.32 | Good |
| 18 | 2.0 | 1.00 | BaS | 0.50 | As ₂ O ₃ | 0.20 | 232 | >10 ¹⁴ | 36 | 100.0 | 0.36 | Good |
| 19 | 2.0 | 1.00 | BaS | 0.50 | WO ₃ | 0.20 | 220 | >10 ¹⁴ | 38 | 100.0 | 0.34 | Good |
| 20 | 2.0 | 1.00 | BaS | 0.50 | Bi ₂ O ₃ | 0.10 | 217 | >10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| 21 | 2.0 | 1.00 | BaS | 0.50 | PbO | 0.10 | 222 | >10 ¹⁴ | 36 | 100.0 | 0.31 | Good |
| 22 | 2.0 | 1.00 | BaS | 0.50 | Sb ₂ O ₃ | 0.10 | 219 | >10 ¹⁴ | 36 | 100.0 | 0.31 | Good |
| 23 | 2.0 | 1.00 | BaS | 0.50 | CdO | 0.30 | 209 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 24 | 2.0 | 1.00 | BaS | 0.50 | ZnO | 0.30 | 237 | >10 ¹⁴ | 32 | 100.0 | 0.37 | Good |
| 25 | 2.0 | 1.00 | MnSi ₂ | 0.50 | As ₂ O ₃ | 0.20 | 199 | >10 ¹⁴ | 35 | 100.0 | 0.37 | Good |
| 26 | 2.0 | 1.00 | MoSi ₂ | 0.50 | WO ₃ | 0.20 | 202 | >10 ¹⁴ | 41 | 100.0 | 0.38 | Good |
| 27 | 2.0 | 1.00 | MnSi ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 210 | >10 ¹⁴ | 31 | 100.0 | 0.37 | Good |
| 28 | 2.0 | 1.00 | MnSi ₂ | 0.50 | CdO | 0.30 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.35 | Good |

Table 9-2

| No. | Y ₂ O ₃ parts by weight | Li parts by weight | Additive | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|--------------------------|-------------------------------------|--------------------|--------------------------------|--------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|
| | | | | parts by weight | | parts by weight | | | | | | |
| 29 | 2.0 | 1.00 | MoSi ₂ | 0.50 | ZnO | 0.30 | 207 | >10 ¹⁴ | 33 | 100.0 | 0.36 | Good |
| 30 | 2.0 | 1.00 | CaH ₂ | 0.50 | Al ₂ O ₃ | 0.20 | 240 | >10 ¹⁴ | 33 | 100.0 | 0.37 | Good |
| 31 | 2.0 | 1.00 | CaH ₂ | 0.50 | Ga ₂ O ₃ | 0.20 | 239 | >10 ¹⁴ | 36 | 100.0 | 0.34 | Good |
| 32 | 2.0 | 1.00 | CaH ₂ | 0.50 | In ₂ O ₃ | 0.20 | 235 | >10 ¹⁴ | 34 | 100.0 | 0.35 | Good |
| 33 | 2.0 | 1.00 | CaH ₂ | 0.50 | W ₂ O ₃ | 0.20 | 230 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 34 | 2.0 | 1.00 | CaH ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 35 | 2.0 | 1.00 | CaH ₂ | 0.50 | PbO | 0.10 | 200 | >10 ¹⁴ | 33 | 100.0 | 0.35 | Good |
| 36 | 2.0 | 1.00 | CaH ₂ | 0.50 | Sb ₂ O ₃ | 0.10 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| 37 | 2.0 | 1.00 | CaH ₂ | 0.50 | CdO | 0.30 | 213 | >10 ¹⁴ | 34 | 100.0 | 0.31 | Good |
| 38 | 2.0 | 1.00 | CaH ₂ | 0.50 | ZnO | 0.30 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 39 | 2.0 | 1.00 | LaB ₆ | 0.20 | W ₂ O ₃ | 0.20 | 238 | >10 ¹⁴ | 36 | 100.0 | 0.35 | Good |
| | | | + CaH ₂ | 0.30 | | | | | | | | |
| 40 | 2.0 | 1.00 | LaB ₆ | 0.50 | Al ₂ O ₃ | 0.20 | 239 | >10 ¹⁴ | 37 | 100.0 | 0.36 | Good |
| | | | | | + CdO | 0.30 | | | | | | |
| 41 | 2.0 | 1.00 | ZnS | 0.20 | CdO | 0.20 | 230 | >10 ¹⁴ | 40 | 100.0 | 0.36 | Good |
| | | | + BaS | 0.30 | + ZnO | 0.20 | | | | | | |
| 42 | 2.0 | 1.00 | CaS | 0.20 | Sb ₂ O ₃ | 0.20 | 244 | >10 ¹⁴ | 39 | 100.0 | 0.30 | Good |
| | | | + CaH ₂ | 0.20 | + PbO | 0.20 | | | | | | |
| | | | + Ca ₃ N ₂ | 0.10 | + ZnO | 1.00 | | | | | | |

Table 10-1

| No. | Y ₂ O ₃ wt % | B wt % | Additive | | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance | |
|-----|---------------------------------------|-----------|--------------------------------|------|--------------------------------|------|--------------------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|------|
| | | | | wt % | | wt % | | | | | | | | |
| 1 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | Li ₂ O | 0.20 | 223 | >10 ¹⁴ | 32 | 100.0 | 0.34 | Good |
| 2 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | K ₂ O | 0.20 | 224 | >10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| 3 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | B ₂ O ₃ | 0.20 | 232 | >10 ¹⁴ | 37 | 100.0 | 0.33 | Good |
| 4 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | SiO ₂ | 0.20 | 218 | >10 ¹⁴ | 35 | 100.0 | 0.34 | Good |
| 5 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | GeO ₂ | 0.20 | 220 | >10 ¹⁴ | 39 | 100.0 | 0.37 | Good |
| 6 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | P ₂ O ₅ | 0.20 | 220 | >10 ¹⁴ | 37 | 100.0 | 0.33 | Good |
| 7 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | As ₂ O ₅ | 0.20 | 218 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 8 | 2.0 | 0.20 | ZnO | 0.50 | Mg ₃ N ₂ | 2.00 | B ₂ O ₃ | 0.10 | 209 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 9 | 2.0 | 0.20 | ZnO | 0.50 | Ca ₃ N ₂ | 2.00 | B ₂ O ₃ | 0.10 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.34 | Good |
| 10 | 2.0 | 0.20 | ZnO | 0.50 | LaB ₆ | 2.00 | B ₂ O ₃ | 0.10 | 233 | >10 ¹⁴ | 33 | 100.0 | 0.33 | Good |
| 11 | 2.0 | 0.20 | ZnO | 0.50 | CaB ₆ | 2.00 | B ₂ O ₃ | 0.10 | 239 | >10 ¹⁴ | 36 | 100.0 | 0.34 | Good |
| 12 | 2.0 | 0.20 | ZnO | 0.50 | CaS | 2.00 | B ₂ O ₃ | 0.10 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 13 | 2.0 | 0.20 | ZnO | 0.50 | Na ₂ S | 2.00 | B ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 35 | 100.0 | 0.25 | Good |
| 14 | 2.0 | 0.20 | ZnO | 0.50 | AlP | 2.00 | B ₂ O ₃ | 0.10 | 215 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 15 | 2.0 | 0.20 | ZnO | 0.50 | Ca ₃ P ₂ | 2.50 | B ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 32 | 100.0 | 0.36 | Good |
| 16 | 2.0 | 0.20 | ZnO | 0.50 | MoSi ₂ | 2.50 | B ₂ O ₃ | 0.10 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.35 | Good |
| 17 | 2.0 | 0.20 | ZnO | 0.50 | Zr ₂ Si | 2.00 | B ₂ O ₃ | 0.10 | 201 | >10 ¹⁴ | 33 | 100.0 | 0.35 | Good |
| 18 | 2.0 | 0.20 | ZnO | 0.50 | CaH ₂ | 2.00 | B ₂ O ₃ | 0.10 | 244 | >10 ¹⁴ | 34 | 100.0 | 0.33 | Good |
| 19 | 2.0 | 0.20 | ZnO | 0.50 | LiAlH ₄ | 2.00 | B ₂ O ₃ | 0.10 | 242 | >10 ¹⁴ | 35 | 100.0 | 0.35 | Good |
| 20 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 230 | >10 ¹⁴ | 36 | 100.0 | 0.32 | Good |
| 21 | 2.0 | 1.00 | Ga ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 228 | >10 ¹⁴ | 33 | 100.0 | 0.35 | Good |
| 22 | 2.0 | 1.00 | In ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 235 | >10 ¹⁴ | 31 | 100.0 | 0.36 | Good |
| 23 | 2.0 | 1.00 | WO ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.34 | Good |
| 24 | 2.0 | 1.00 | Bi ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 211 | >10 ¹⁴ | 38 | 100.0 | 0.35 | Good |
| 25 | 2.0 | 1.00 | PbO | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 217 | >10 ¹⁴ | 37 | 100.0 | 0.34 | Good |
| 26 | 2.0 | 1.00 | Sb ₂ O ₃ | 1.00 | CaH ₂ | 1.00 | Li ₂ O | 1.00 | 215 | >10 ¹⁴ | 35 | 100.0 | 0.33 | Good |
| 27 | 2.0 | 1.00 | CdO | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.32 | Good |

Table 10-2

| No. | Y ₂ O ₃ parts by weight | B parts by weight | Additive | | | | | | Thermal conductivity W/mK | Insulation resistance Ωcm | Strength kg/mm ² | Relative density % | Surface roughness Ra (μm) | Appearance |
|-----|---|-------------------------|---|----------------------|---|----------------------|--|----------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------------|------------|
| | | | | parts by weight | | parts by weight | | parts by weight | | | | | | |
| 28 | 1.0 | 0.5 | Al ₂ O ₃ + SiO ₂ | 1.00 | LaB ₆ | 1.00 | B ₂ O ₃ | 0.50 | 241 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 29 | 1.0 | 0.5 | GeO ₂ | 1.00 | LaB ₆ + CaH ₂ | 0.50 0.30 | B ₂ O ₃ | 0.50 | 243 | >10 ¹⁴ | 36 | 100.0 | 0.35 | Good |
| 30 | 2.0 | 1.0 | Al ₂ O ₃ | 1.00 | CuS | 0.50 | B ₂ O ₃ + Na ₂ O | 0.20 0.30 | 243 | >10 ¹⁴ | 36 | 100.0 | 0.33 | Good |
| 31 | 2.0 | 1.0 | Al ₂ O ₃ + WO ₃ | 1.00 | CuS + CaH ₂ | 0.20 0.30 | P ₂ O ₅ | 0.20 | 244 | >10 ¹⁴ | 34 | 100.0 | 0.35 | Good |
| 32 | 2.0 | 1.0 | CdO | 1.00 | CuS + CaH ₂ | 0.20 0.30 | B ₂ O ₃ + P ₂ O ₅ | 0.20 0.20 | 246 | >10 ¹⁴ | 33 | 100.0 | 0.34 | Good |
| 33 | 2.0 | 1.0 | CdO + ZnO | 0.40 0.40 | CdS + ZnS | 0.20 0.30 | B ₂ O ₃ + P ₂ O ₅ | 0.20 0.20 | 244 | >10 ¹⁴ | 39 | 100.0 | 0.32 | Good |
| 34 | 2.0 | 1.0 | Al ₂ O ₃ | 0.20 | CuS + CaH ₂ + Ca ₃ N ₂ | 0.20 0.20 0.20 | B ₂ O ₃ + SiO ₂ + Li ₂ O | 0.20 0.20 0.20 | 246 | >10 ¹⁴ | 40 | 100.0 | 0.35 | Good |
| 35 | 2.0 | 1.0 | Al ₂ O ₃ + In ₂ O ₃ + PbO | 1.00 0.01 0.01 | CuS + CaH ₂ + Ca ₃ N ₂ | 0.01 0.10 2.00 | B ₂ O ₃ + SiO ₂ + Li ₂ O | 0.30 0.01 0.02 | 248 | >10 ¹⁴ | 41 | 100.0 | 0.35 | Good |

Continuation from page 1

(72) inventor Suguru YAMAMURA

c/o Technology and Research Center

Kawasaki Steel Corporation

Kawasaki-cho 1, Chiba C., Chiba Pre.

(72) inventor Toshihiko FUNAHASHI

c/o Technology and Research Center

Kawasaki Steel Corporation

Kawasaki-cho 1, Chiba C., Chiba Pre.

(72) inventor Masato Kumagai

c/o Technology and Research Center

Kawasaki Steel Corporation

Kawasaki-cho 1, Chiba C., Chiba Pre.

Written Amendment (Voluntary)

May 11, 1990

Commissioner Fumitake YOSHIDA

1. The matter concerned

Patent application No. 95385 in 1989

2. Title of the invention

METHOD FOR PRODUCING ALUMINUM NITRIDE SINTERED
BODY

3. Person claiming the amendment

relation to the matter: Patent applicant

Kawasaki Steel Corporation

(125) 1-1-28 Kitahoncho-dori, Chuo-ku, Kobe C.

4. Representative patent attorney (7917) Yoshio KOSUGI

2nd Kusuda Building 4th F.

(105) 1-1-28 Nishi-shinjuku, Shinjuku-ku, Tokyo

tel: 03-508-9104

5. The number of inventions to be increased by the amendment none

6. The object to be amended

The paragraph of "Detailed description of the Invention".

7. The content of the amendment

(1) A phrase "when it exceeds 2000°C" is inserted before the word "AlN particles" in the 11th line of page 20 in the specification.

⑨ 日本国特許庁(JP)

⑩ 特許出願公開

⑫ 公開特許公報(A)

平2-275765

⑮ Int. Cl.⁹
C 04 B 35/58

識別記号 庁内整理番号
1 0 4 B 7412-4C

⑬ 公開 平成2年(1990)11月9日

審査請求 未請求 請求項の数 8 (全16頁)

⑭ 発明の名称 窒化アルミニウム焼結体の製造方法

⑰ 特 願 平1-95385

⑱ 出 願 平1(1989)4月17日

⑲ 発 明 者 中 野 正 千葉県千葉市川崎町1番地 川崎製鉄株式会社技術研究本部内
⑲ 発 明 者 横 井 誠 千葉県千葉市川崎町1番地 川崎製鉄株式会社技術研究本部内
⑲ 発 明 者 金 丸 孝 男 千葉県千葉市川崎町1番地 川崎製鉄株式会社技術研究本部内
⑲ 発 明 者 要 鹿 哲 也 千葉県千葉市川崎町1番地 川崎製鉄株式会社技術研究本部内

⑳ 出 願 人 川崎製鉄株式会社 兵庫県神戸市中央区北本町通1丁目1番28号

㉑ 代 理 人 弁理士 小杉 佳男

最終頁に続く

明 細 書

1. 発明の名称

窒化アルミニウム焼結体の製造方法

2. 特許請求の範囲

1 窒化アルミ粉末100重量部に焼結助剤として

(イ) イットリウム、スカンジウムおよびランタノイドの酸化物の群から選ばれた1種または2種以上を酸化物に換算して0.05～5重量部

(ロ) 金属リチウム、金属ベリリウム、金属マグネシウム、硼素、珪素、硫黄、炭、砒素および金属亜鉛の群より選ばれた単体の1種または2種以上を0.01～5重量部を添加し、該混合粉末を成形し、非酸化性雰囲気中で1400℃～2000℃の温度範囲において焼成することを特徴とする窒化アルミニウム焼結体の製造方法。

2 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ハ) アルカリ金属の酸化物および2000℃以下の加熱により酸化物となるアルカリ金属化合物並びに硼素、珪素、ゲルマニウム、砒素および炭の酸化物および2000℃以下の加熱によりこれらの酸化物となる化合物の群から選ばれた1種または2種以上を酸化物に換算して0.01～5重量部

を添加することを特徴とする請求項1記載の窒化アルミニウム焼結体の製造方法。

3 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ニ) 金属硼化物、金属窒化物、金属炭化物、金属硫化物、金属珪化物、および金属水素化合物の群より選ばれた化合物の群より選ばれた化合物のうち1種または2種以上を0.01～5重量部

添加することを特徴とする請求項1記載の窒化アルミニウム焼結体の製造方法。

4 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ニ) 金属硼化物、金属窒化物、金属燐化物、金属硫化合物、金属珪化合物、および金属水素化合物の群より選ばれる化合物の群より選ばれた化合物のうち1種または2種以上を0.01～5重量部

を添加することを特徴とする請求項2記載の窒化アルミニウム焼結体の製造方法。

- 5 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ホ) アルミニウム、ガリウム、インジウム、タングステン、ビスマス、鉛、アンチモン、カドミウム、亜鉛の酸化物および2000℃以下の加熱によりこれらの酸化物となる化合物の1種または2種以上を酸化物に換算して0.01～2重量部

を添加することを特徴とする請求項1記載の窒化アルミニウム焼結体の製造方法。

- 6 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ハ) アルカリ金属の酸化物および2000

物、金属硫化合物、金属珪化合物、および金属水素化合物の群より選ばれる化合物の群より選ばれた化合物のうち1種または2種以上を0.01～5重量部

を添加することを特徴とする請求項6記載の窒化アルミニウム焼結体の製造方法。

3. 発明の詳細な説明

〔産業上の利用分野〕

本発明は窒化アルミニウム焼結体の製造方法に関し、特に産業上の要求の高い熱伝導率の高い窒化アルミニウム焼結体の製造方法に関する。

〔従来の技術〕

高熱伝導率AlN焼結体の用途は具体的には半導体用基板材料を代表例として絶縁材料として使われる。

半導体の高集積化、高速化、高出力化などの動向に伴って、以下のような問題がクローズアップされてきている。すなわち、

- ① 半導体チップの発熱を如何に効率よく系外に逃すか。

て以下の加熱により酸化物となるアルカリ金属化合物並びに硼素、珪素、ゲルマニウム、亜鉛および燐の酸化物および2000℃以下の加熱によりこれらの酸化物となる化合物の群から選ばれた1種または2種以上を酸化物に換算して0.01～5重量部

を添加することを特徴とする請求項5記載の窒化アルミニウム焼結体の製造方法。

- 7 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ニ) 金属硼化物、金属窒化物、金属燐化物、金属硫化合物、金属珪化合物、および金属水素化合物の群より選ばれる化合物の群より選ばれた化合物のうち1種または2種以上を0.01～5重量部

を添加することを特徴とする請求項5記載の窒化アルミニウム焼結体の製造方法。

- 8 窒化アルミ粉末100重量部に焼結助剤としてさらに、

(ニ) 金属硼化物、金属窒化物、金属燐化

- ② 動作速度の向上につれて基板またはパッケージ部分の信号の遅延が問題となる。
③ チップサイズの増大によりチップと基板との熱膨張差が大きくなり、接合の信頼性が低下する。
④ 高電力チップでは使用電圧がますます増大しており、基板の絶縁破壊が問題となりつつある。

半導体が抱えるこのような問題を解決し得る、従来のアルミナに代る基板、パッケージ用セラミックスとしては、

- ① 熱伝導率が高い。
② 電気絶縁性が優れる。
③ 高周波特性が良い。(低誘電率、低誘電損失)
④ 熱膨張率がSiまたはGaAsに近い。
⑤ 化学的に安定である。
⑥ 機械的な強度が大きい。
⑦ 回路形成が容易である。
⑧ 気密封止ができる。
などの特性を有することが望ましい。

このような特性を基本的に有するものとしてA₂Nが有望視されているわけである。

しかし、具体的にA₂Nセラミックスを適用しようとする、以下の最低限特性項目を満たす必要がある。すなわち、

- (1) 焼結体が均一で緻密であること。機械的強度が大なること。相対密度が95%以上あることが望ましい。
- (2) 熱伝導率ができるだけ高いこと。
- (3) 体積抵抗が高いこと。 $10^{12}\Omega\cdot\text{cm}$ 以上必要。
- (4) 焼結体表面が平滑・平坦であること。

上記のうち、(4)の項目は必須ではないといいいながら、大量生産で基板を製造する際には、加工を省略し製造コストを下げるという意味があり、製造技術上は必須である。具体的には、焼き放しで表面粗さがRaで $0.5\mu\text{m}$ 以下、反りが $0.1\text{mm}/50\text{mm}$ 以下であることが望ましい。

従来の技術では上記項目の(1)、(2)を満

しかし、これらの方法はA₂N表層の薄い酸素膜を取り除くため、A₂Nの難焼結性が顕著に現われ、焼結助剤を添加しても生産性が低く、高価なホットプレスによらないと所望の焼結体が得られず、大量生産向きではない。

また、炭素協会誌、第25回炭素基礎討論会、1D03、3H03(昭和62年1月)ではA₂N成形体を還元雰囲気中、 $1850\sim 1950^\circ\text{C}$ で2~96hr焼結することにより、高熱伝導率のA₂N焼結体を得る方法を示しているが、これとて高熱伝導性に優れたA₂N基板となり得る焼結体が得られない。

一方、特開昭62-52181に、A₂Nに焼結助剤として炭素換算で0.2~3.4重量部の炭素、酸化イットリウム0.1~10重量部を含有させた成形体を $1600\sim 2100^\circ\text{C}$ で焼結することを特徴とするA₂N焼結体の製造方法が開示されている。しかし、この発明は以下の点に全く触れておらずまた、以下の問題のためA₂N基板の製造方法として満足なものとはいえなかった。す

足させるため、特公昭46-41003に示されるように、Y₂O₃を焼結助剤として用いたり、または特公昭58-49510に示されるように、CaO、BaO、SrOなどを焼結助剤として用い、熱伝導率が $100\text{W}/\text{m}\cdot\text{K}$ 程度のセラミックスが得られている。しかし、使用客側から、用途によって更に高い熱伝導特性を有する焼結体が要求されている。

これまで、高熱伝導率A₂N焼結体を得る方法としては、

- (i) A₂N粉末を非酸化性雰囲気中 1600°C 以上で熱処理し、粉末の酸素含有量を低減した後焼結する方法。(特開昭61-201668)
- (ii) 熱処理後のA₂N粉末を $1800\sim 2300^\circ\text{C}$ 、非酸化性雰囲気下で $20\text{kg}/\text{cm}^2$ 以上の圧力下でホットプレスし、最高 $210\text{W}/\text{m}\cdot\text{K}$ の熱伝導率を得る方法(特開昭61-201668)

がある。

なわち、

- (1) 焼結体密度が低いこと。
- (2) 電気絶縁特性が得られない。
- (3) 着色・焼結ムラが発生する。

また、特開昭61-127667号、61-219763号にはA₂N、Y₂O₃、Cを助剤として添加した技術が開示されているが、上述と同様の理由でA₂N基板としては適さない。また、特開昭63-236765についても同じである。

[発明が解決しようとする課題]

以上の従来の方法による焼結体では、

- (a) 熱伝導率が不十分である。
- (b) ホットプレス等設備コストが高く、生産性の低い炉でしか焼結できない。
- (c) 電気絶縁性がない。
- (d) 安定した品質が得られない。

といった問題点があった。このようにこれまでの発明は前記(a)~(d)の4項目をすべて満足するものとは言い難かった。

従って、このような点を改善するため、新たな高熱伝導率A₂N焼結体の製造方法の開発が望まれていた。

本発明は前記(a)～(d)の4項目の問題点を全て満たすA₂N焼結体の高熱伝導化方法を提供することを目的とするものである。すなわち、緻密で熱伝導率および電気抵抗が高く、電気絶縁基板に代表される材料として好適な性能を有する安価なA₂N焼結体の製造方法を提供することにある。

〔課題を解決するための手段〕

本発明者らは、以上述べた従来技術の問題点に鑑み、窒化アルミニウム焼結体の熱伝導率を向上し、基板として必要な特性を具備させるべく研究を重ねた結果、以下に示す新規事項を発見し本発明に至ったものである。

すなわち、A₂N粉末にREMおよび金属リチウム、金属ベリリウム、金属マグネシウム、硼素、珪素、硫黄、燐、砒素および金属亜鉛の群より選ばれた単体の1種または2種以上を添加した

成形し、得られた成形体を非酸化性雰囲気中で1400～2000℃の温度範囲で焼成することにより達成することができる。これらの成分の群は次の通りである。

(イ) イットリウム、スカンジウムおよびランタノイドの酸化物の群から選ばれた1種または2種以上を酸化物に換算して0.05～5重量部

(ロ) 金属リチウム、金属ベリリウム、金属マグネシウム、硼素、珪素、硫黄、燐、砒素および金属亜鉛の群より選ばれた単体の1種または2種以上を0.01～5重量部

(ハ) アルカリ金属の酸化物および2000℃以下の加熱により酸化物となるアルカリ金属化合物並びに硼素、珪素、ゲルマニウム、砒素および燐の酸化物および2000℃以下の加熱によりこれらの酸化物となる化合物の群から選ばれた1種または2種以上を酸化物に換算して0.01～5重量部

(ニ) 金属硼化物、金属窒化物、金属燐化物、

シート成形体を非酸化性雰囲気中で焼結したところ、熱伝導率の高いセラミックス焼結体を得た。ここにREMとはイットリウム、スカンジウムおよびランタノイドを指称する。

上記焼結体は前記絶縁基板として要求される上記(a)～(d)の要求を全て満足するものであった。

この事実に基づき、上記要求の最適添加範囲、他の元素および化合物について広範囲な検討を行った結果、本発明を完成した。添加元素、またはその化合物およびその添加範囲を限定して選択すれば、相対密度が95%以上、熱伝導率が160W/m・K以上、焼き上がりの表面の粗さがRaで0.5μm以下、体積抵抗が10¹²Ω・cm以上で、焼きムラのない窒化アルミニウム高熱伝導性・電気絶縁性焼結体が得られる。

上記焼結体の製造方法は以下の通りである。

すなわち、窒化アルミニウム粉末100重量部に次の(イ)～(ホ)の群から選ばれた成分の組合わせからなる焼結助剤を添加し、これを

金属硼化物、金属珪化物、および金属水素化合物の群より選ばれる化合物の群より選ばれた化合物のうち1種または2種以上を0.01～5重量部

(ホ) アルミニウム、ガリウム、インジウム、タングステン、ビスマス、鉛、アンチモン、カドミウム、亜鉛の酸化物および2000℃以下の加熱によりこれらの酸化物となる化合物の1種または2種以上を酸化物に換算して0.01～2重量部

上記の成分の群の組合わせは次の通りである。

- ① (イ) + (ロ)
- ② (イ) + (ロ) + (ハ)
- ③ (イ) + (ロ) + (ニ)
- ④ (イ) + (ロ) + (ハ) + (ニ)
- ⑤ (イ) + (ロ) + (ホ)
- ⑥ (イ) + (ロ) + (ホ) + (ハ)
- ⑦ (イ) + (ロ) + (ホ) + (ニ)
- ⑧ (イ) + (ロ) + (ホ) + (ハ) + (ニ)

〔作用〕

これらの焼結助剤の複合添加が有効であるメカニズムについては十分解明されてはいないが、以下のように考えられる。

A & Nの表面には、完全な Al_2O_3 にはなっていないくともある種の Al 酸化物が存在している。この酸化物を仮に Al_2O_3 とすると、加えた上記(イ)成分、例えば Y_2O_3 との間に液相 $xAl_2O_3 \cdot yY_2O_3$ を生成する。次に、

(ロ)成分である金属リチウム、金属ベリリウム、金属マグネシウム、硼素、珪素、硫黄、塩、砒素、金属亜鉛は、いずれも強い還元剤であり、酸化アルミニウム中の不純物酸素と反応し、これを除去する。すなわち、液相の生成から粒成長に至る段階で、A & N表面の酸素は上記(ロ)成分により還元され減量しながらA & N粒を浄化していく。

この結果として得られた焼結体は、高熱伝導・電気絶縁性基板用焼結体として理想的なものができ上がるものと考えられる。

上記(イ)成分の添加量がA & N 100重量部

が高く、メタライズ性のばらつきの少ない焼結体を得ることができる。

(ハ)成分の添加量は0.01重量部より少ないと残存する粒界相の分布不均一による焼きムラが生じやすい。5重量部より多いと、焼結時に異常粒成長の発生が見られ、機械的強度が低くなる。

また、前記(イ)成分、(ロ)成分に(ニ)成分、すなわち金属硼化物、金属窒化物、金属燐化物、金属硫化物、金属珪化物、金属水素化物を加えると、これらは、いずれも酸素と化合し易く、A & N結晶中の不純物酸素と容易に反応し、これを除去すると同時に、反応生成物が液相となって粒界に浸透し、焼結を促進する効果を発揮する。

同時に添加した(イ)成分は、高温で液相となって焼結を著しく促進する。また、(ロ)成分の強い還元作用によって、粒成長過程において酸素と化合し、揮散させ、さらにA & Nの熱伝導率を高めることができる。

上記(ニ)成分の添加量はA & N 100重量部に対して0.01~5重量部である。0.01重量部

に対して0.05重量部より少ないと熱伝導率が上がらないため、要求を満たさない。5重量部より多いとやはり粒界相の量が多くなるため熱伝導率が低下する。

また、上記(ロ)成分すなわち還元剤成分の添加量は、A & N 100重量部に対して0.01重量部より少ないと粒界相の分布が不均一となり、結状の模様が生ずる。2重量部より多いとYNが残存し、部分的な着色が発生し、見映えが悪い。さらに、添加量を増やすと、昇温時の収縮速度が遅くなり、粒界相が揮発してしまうため、よく焼結しない。

次に上記(イ)成分、(ロ)成分に(ハ)成分を加えると、(ハ)成分はアルカリ金属酸化物、またはグラスフォーマー元素酸化物であって、より低温で液相を生成するため粒界液相による焼結促進に寄与し、A & Nの表面酸化物を除去し、またガラス生成により粒界の均一化、および浸透によるA & N結晶粒の異常成長を抑制する。従って粒径が均一となり高熱伝導率、高密度で絶縁抵抗

未満では不純物酸素除去の効果が乏しく、5重量%を超えて添加しても、添加効果の向上がない。

さらに、前記(イ)成分、(ロ)成分に(ハ)成分および(ニ)成分を複合添加すると、酸素の低減効果と、液相生成温度の低下効果の相乗効果によって、熱伝導率の高いA & N基板を得ることができる。この場合、(ハ)成分および(ニ)成分の添加量はA & N 100重量部に対してそれぞれ0.01~5重量部とすればよい。

これらの(ハ)、(ニ)成分に代わり、前記(イ)成分、(ロ)成分に、(ホ)成分すなわち両性酸化物であるアルミニウム、ガリウム、インジウム、タングステン、ビスマス、鉛、アンチモン、カドミウム、亜鉛の酸化物を添加することによって、高熱伝導率のA & Nを得ることができる。(ホ)成分の作用は次のように考えられる。

(ホ)成分の化合物は焼結過程でA & N中に存在するFe、Ti等の不純物と反応して粒界に化合物を形成し、これらをトラップする。A & N

中に存在するFe、Ti等は熱伝導を妨げるもので、これが除去されると熱伝導率が向上する。

(ホ)成分の添加量はAlN100重量部に対して0.01~5重量部である。0.01重量部未満ではFe、Ti等と反応して化合物を生成する効果が乏しく、5重量%を超えて添加しても、添加効果の向上がない。

上記(イ)成分、(ロ)成分、(ホ)成分にさらに(ハ)成分または/および(ニ)成分を加えた四元または五元の焼結助剤も有効である。この場合、それぞれの成分の有する特性が発揮され、その相乗効果によって、AlNの熱伝導率が向上する。

次に、(イ)成分として Y_2O_3 、(ロ)の成分として金属Znを例として本発明の製品の製造方法の具体例について述べる。

平均粒径0.1~3 μm の窒化アルミニウム粉100重量部に Y_2O_3 を0.5~5重量部、金属Znを0.01~0.5重量部の範囲で添加し、混合、分散を行い、バインダを添加し成形体を作成

タ、パワダイオード、レーザーダイオード用のヒートシンク等、産業上の応用が可能である。

【実施例】

実施例1

平均粒径1 μm のAlN粉末100重量部に、第1表に示す量の平均粒径1 μm の Y_2O_3 粉末と、平均粒径6 μm のMg粉末とをトルエンエタノール混合溶媒と共に添加し、ボールミルにて十分混合、解砕した後、バインダとしてポリビニルブチラール樹脂を添加し、AlNスラリーを調製した。これを用い、ドクターブレード法にてグリーンシートを作成し、65×65mm角に打ち抜き加工し、グリーン成形体を得た。

これらを N_2 中にて700℃で脱脂した後、 N_2 雰囲気中常圧下で1800℃で3時間焼成し、AlN板を得た。

得られたAlN板について、外観、相対密度、熱伝導率、絶縁抵抗、表面粗度等絶縁性基板として一般に必要とされる特性を測定した。その結果を第1表に示す。

成形法としては、ドクターブレード法、プレス成形法、鋳込み成形法、押出し成形法等の、一般によく知られた方法をとることができる。これより得られた成形体を非酸化性雰囲気中で1400~2000℃で焼成する。

高熱伝導率のAlN焼結体を得るには、AlNの不純物酸素が低いほど望ましいが約1重量部以下であればよい。

焼成はAlNルツボ中にて行うが焼成温度は1400℃以下では、焼結が途中で停止しており、AlN粒の昇華によるマイクロポアが発生し、熱伝導率を低減させる。

酸素濃度500ppm以上の雰囲気中で焼成するとAlNの酸化が起こり、高熱伝導性の焼結体は得られない。

【発明の効果】

本発明により160W/m・K以上の熱伝導率を有する窒化アルミニウム焼結体とそれを基材にする電気絶縁体が提供でき、ハイブリッドIC用基板、サーディップ用基板、パワートランジス

特性のうち、相対密度はアルキメデス法にて焼結体密度を求め、真密度で除して、%表示で示した。

熱伝導率はレーザーフラッシュ法を用いて測定した。絶縁抵抗率は絶縁計を用い測定した。表面粗度(Ra)は触針式表面粗度計にて測定した。

実施例2

原料のうち、Mg粉末に替えて第2表に示す各種元素を用いた他は、実施例1と同一の方法にてAlN板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第2表に示した。

実施例3

原料のうち、 Y_2O_3 に替えて第3表に示す各種希土類酸化物を用いた他は、実施例1と同一の方法にてAlN板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第3表に示した。

実施例4

平均粒径1 μm のAlN粉末100重量部に、

第4表に示す量の平均粒径 $1\mu\text{m}$ の Y_2O_3 粉末と、平均粒径 $3\mu\text{m}$ のB、および第4表に示した各種酸化物をトルエン-エタノール混合溶媒と共に添加し、ボールミルにて十分混合、解砕した後、バインダとしてポリビニルブチラール樹脂を添加し、A&Nスラリーを調製した。これを用い、ドクターブレード法にてグリーンシートを作成し、 $65\times 65\text{mm}$ 角に打ち抜き加工し、グリーン成形体を得た。

これらを N_2 中にて 700°C で脱脂した後、 N_2 雰囲気中常圧下で 1800°C で3時間焼成し、A&N板を得た。

得られたA&N板について、外観、相対密度、熱伝導率、絶縁抵抗、表面粗度等絶縁性基板として一般に必要とされる特性を測定した。その結果を第4表に示す。

特性のうち、相対密度はアルキメデス法にて焼結体密度を求め、真密度で除して、%表示で示した。

熱伝導率はレーザーフラッシュ法を用いて測定

した。絶縁抵抗率は絶縁計を用い測定した。表面粗度(Ra)は触針式表面粗度計に測定した。

実施例5

平均粒径 $1\mu\text{m}$ のA&N粉末100重量部に、第5表に示す量の平均粒径 $1\mu\text{m}$ の Y_2O_3 粉末、平均粒径 $3\mu\text{m}$ のB、および第5表に示した各種化合物をトルエン-エタノール混合溶媒と共に添加し、ボールミルにて十分混合、解砕した後、バインダとしてポリビニルブチラール樹脂を添加し、A&Nスラリーを調製した。これを用い、ドクターブレード法にてグリーンシートを作成し、 $65\times 65\text{mm}$ 角に打ち抜き加工し、グリーン成形体を得た。

これらを N_2 中にて 700°C で脱脂した後、 N_2 雰囲気中常圧下で 1800°C で3時間焼成し、A&N板を得た。

得られたA&N板について、外観、相対密度、熱伝導率、絶縁抵抗、表面粗度等絶縁性基板として一般に必要とされる特性を測定した。その結果を第5表に示す。

特性のうち、相対密度はアルキメデス法にて焼結体密度を求め、真密度で除して、%表示で示した。

熱伝導率はレーザーフラッシュ法を用いて測定した。絶縁抵抗率は絶縁計を用い測定した。表面粗度(Ra)は触針式表面粗度計にて測定した。

実施例6

原料に、 Y_2O_3 、B、および第6表に示す各種化合物を用いた他は、実施例5と同一の方法にてA&N板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第6表に示した。

実施例7

原料に、 Y_2O_3 、B、および第7表に示す各種化合物を用いた他は、実施例5と同一の方法にてA&N板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第7表に示した。

実施例8

原料に、 Y_2O_3 、Zn粉末、および第8表に

示す各種化合物を用いた他は、実施例5と同一の方法にてA&N板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第8表に示した。

実施例9

原料に、 Y_2O_3 、金属Li、および第9表に示す各種化合物を用いた他は、実施例5と同一の方法にてA&N板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第9表に示した。

実施例10

原料に、 Y_2O_3 、B、および第10表に示す各種化合物を用いた他は、実施例5と同一の方法にてA&N板を作成し、その外観、相対密度、熱伝導率、絶縁抵抗、表面粗度を測定し、その結果を第10表に示した。

第 1 表

| No. | Y ₂ O ₃ 重量部 | Mg 重量部 | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 密度 kg/mm ³ | 相対密度 % | 表面粗度 Ra (μm) | 外觀 | 備 考 |
|-----|--------------------------------------|-----------|--------------|-------------------|--------------------------|-----------|-----------------|-----|-----|
| 1 | 0.1 | 0 | 130 | >10 ¹⁴ | 28 | 98.0 | 0.33 | 色ムラ | 比較例 |
| 2 | 0.1 | 0.05 | 175 | >10 ¹⁴ | 30 | 99.1 | 0.28 | 良好 | 実施例 |
| 3 | 0.1 | 0.10 | 179 | >10 ¹⁴ | 30 | 99.4 | 0.30 | 良好 | " |
| 4 | 0.1 | 0.30 | 188 | >10 ¹⁴ | 31 | 99.5 | 0.31 | 良好 | " |
| 5 | 0.1 | 0.50 | 191 | >10 ¹⁴ | 30 | 99.7 | 0.30 | 良好 | " |
| 6 | 0.1 | 2.00 | 192 | >10 ¹⁴ | 31 | 99.8 | 0.30 | 良好 | " |
| 7 | 1.0 | 0.05 | 203 | >10 ¹⁴ | 33 | 99.9 | 0.32 | 良好 | " |
| 8 | 1.0 | 0.10 | 210 | >10 ¹⁴ | 34 | 99.8 | 0.33 | 良好 | " |
| 9 | 1.0 | 0.30 | 214 | >10 ¹⁴ | 33 | 99.9 | 0.33 | 良好 | " |
| 10 | 1.0 | 0.50 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 | " |
| 11 | 2.0 | 0.05 | 214 | >10 ¹⁴ | 36 | 100.0 | 0.34 | 良好 | " |
| 12 | 2.0 | 0.10 | 218 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 | " |
| 13 | 2.0 | 0.30 | 220 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 | " |
| 14 | 2.0 | 0.50 | 221 | >10 ¹⁴ | 33 | 100.0 | 0.35 | 良好 | " |
| 15 | 2.0 | 2.00 | 218 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 | " |
| 16 | 3.0 | 0.05 | 200 | >10 ¹⁴ | 35 | 100.0 | 0.38 | 良好 | " |
| 17 | 3.0 | 0.10 | 199 | >10 ¹⁴ | 36 | 100.0 | 0.36 | 良好 | " |
| 18 | 3.0 | 0.30 | 204 | >10 ¹⁴ | 39 | 100.0 | 0.37 | 良好 | " |
| 19 | 3.0 | 0.50 | 206 | >10 ¹⁴ | 32 | 100.0 | 0.36 | 良好 | " |
| 20 | 3.0 | 2.00 | 199 | >10 ¹⁴ | 34 | 100.0 | 0.38 | 良好 | " |
| 21 | 5.0 | 0.05 | 190 | >10 ¹⁴ | 31 | 99.2 | 0.39 | 良好 | " |
| 22 | 5.0 | 0.10 | 191 | >10 ¹⁴ | 34 | 99.2 | 0.38 | 良好 | " |
| 23 | 5.0 | 0.30 | 188 | >10 ¹⁴ | 34 | 99.2 | 0.40 | 良好 | " |
| 24 | 5.0 | 0.50 | 186 | >10 ¹⁴ | 33 | 99.0 | 0.42 | 良好 | " |
| 25 | 5.0 | 2.00 | 180 | >10 ¹⁴ | 32 | 99.1 | 0.40 | 良好 | " |

第 2 表

| No. | Y ₂ O ₃ 重量部 | 添 加 剤 重量部 | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 密度 kg/mm ³ | 相対密度 % | 表面粗度 Ra (μm) | 外觀 |
|-----|--------------------------------------|--|--------------|-------------------|--------------------------|-----------|-----------------|----|
| 1 | 2.0 | Li 0.05 | 198 | >10 ¹⁴ | 34 | 100.0 | 0.36 | 良好 |
| 2 | 2.0 | Li 0.50 | 190 | >10 ¹⁴ | 35 | 100.0 | 0.37 | 良好 |
| 3 | 2.0 | Li 5.00 | 175 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 4 | 2.0 | Be 0.05 | 230 | >10 ¹⁴ | 36 | 100.0 | 0.35 | 良好 |
| 5 | 2.0 | Be 0.50 | 236 | >10 ¹⁴ | 39 | 100.0 | 0.32 | 良好 |
| 6 | 2.0 | Be 5.00 | 233 | >10 ¹⁴ | 39 | 100.0 | 0.34 | 良好 |
| 7 | 2.0 | Si 0.05 | 170 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 8 | 2.0 | Si 0.50 | 172 | >10 ¹⁴ | 35 | 100.0 | 0.35 | 良好 |
| 9 | 2.0 | Si 5.00 | 171 | >10 ¹⁴ | 32 | 100.0 | 0.34 | 良好 |
| 10 | 2.0 | B 0.05 | 210 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 11 | 2.0 | B 0.50 | 214 | >10 ¹⁴ | 31 | 100.0 | 0.35 | 良好 |
| 12 | 2.0 | B 5.00 | 218 | >10 ¹⁴ | 32 | 100.0 | 0.34 | 良好 |
| 13 | 2.0 | S 0.05 | 179 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 |
| 14 | 2.0 | S 0.50 | 190 | >10 ¹⁴ | 38 | 100.0 | 0.35 | 良好 |
| 15 | 2.0 | S 5.00 | 191 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 16 | 2.0 | As 0.05 | 191 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 17 | 2.0 | As 0.50 | 193 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 18 | 2.0 | As 5.00 | 193 | >10 ¹⁴ | 32 | 100.0 | 0.34 | 良好 |
| 19 | 2.0 | P 0.05 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 |
| 20 | 2.0 | P 0.50 | 208 | >10 ¹⁴ | 39 | 100.0 | 0.34 | 良好 |
| 21 | 2.0 | P 5.00 | 211 | >10 ¹⁴ | 31 | 100.0 | 0.33 | 良好 |
| 22 | 2.0 | Zn 0.05 | 207 | >10 ¹⁴ | 30 | 100.0 | 0.34 | 良好 |
| 23 | 2.0 | Zn 0.50 | 209 | >10 ¹⁴ | 29 | 100.0 | 0.35 | 良好 |
| 24 | 2.0 | Zn 5.00 | 208 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 25 | 2.0 | Zn _B 3.00 | 212 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 |
| 26 | 2.0 | Li _B 0.05 2.00 | 210 | >10 ¹⁴ | 37 | 100.0 | 0.37 | 良好 |
| 27 | 2.0 | P 1.00 S 1.00 | 222 | >10 ¹⁴ | 39 | 100.0 | 0.34 | 良好 |
| 28 | 2.0 | Li _B 1.00 Zn _B 1.00 | 228 | >10 ¹⁴ | 38 | 100.0 | 0.31 | 良好 |

第 3 表 - 1

| 添加剤 | 重量部 | Mg 重量部 | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相対密度 % | 表面粗度 Ra(μm) | 外観 |
|--------------------------------|------|-----------|--------------|-------------------|--------------------------|-----------|----------------|----|
| La ₂ O ₃ | 0.01 | 1.0 | 184 | >10 ¹⁴ | 30 | 99.8 | 0.33 | 良好 |
| | 0.10 | 1.0 | 231 | >10 ¹⁴ | 32 | 99.9 | 0.33 | 良好 |
| | 1.00 | 1.0 | 232 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| | 2.00 | 1.0 | 223 | >10 ¹⁴ | 36 | 100.0 | 0.36 | 良好 |
| | 5.00 | 1.0 | 225 | >10 ¹⁴ | 31 | 100.0 | 0.37 | 良好 |
| CeO ₂ | 0.01 | 1.0 | 191 | >10 ¹⁴ | 34 | 99.8 | 0.28 | 良好 |
| | 0.10 | 1.0 | 193 | >10 ¹⁴ | 32 | 99.8 | 0.29 | 良好 |
| | 1.00 | 1.0 | 193 | >10 ¹⁴ | 31 | 99.9 | 0.31 | 良好 |
| | 2.00 | 1.0 | 200 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| | 5.00 | 1.0 | 204 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| Nd ₂ O ₃ | 0.01 | 1.0 | 193 | >10 ¹⁴ | 33 | 99.9 | 0.30 | 良好 |
| | 0.10 | 1.0 | 198 | >10 ¹⁴ | 32 | 100.0 | 0.30 | 良好 |
| | 1.00 | 1.0 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.31 | 良好 |
| | 2.00 | 1.0 | 232 | >10 ¹⁴ | 35 | 100.0 | 0.34 | 良好 |
| | 5.00 | 1.0 | 208 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 |
| Sm ₂ O ₃ | 0.01 | 1.0 | 179 | >10 ¹⁴ | 33 | 99.9 | 0.29 | 良好 |
| | 0.10 | 1.0 | 197 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| | 1.00 | 1.0 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.38 | 良好 |
| | 2.00 | 1.0 | 214 | >10 ¹⁴ | 32 | 100.0 | 0.40 | 良好 |
| | 5.00 | 1.0 | 211 | >10 ¹⁴ | 38 | 100.0 | 0.42 | 良好 |

第 3 表 - 2

| 添加剤 | 重量部 | Mg 重量部 | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相対密度 % | 表面粗度 Ra(μm) | 外観 |
|--|----------------------|-----------|--------------|-------------------|--------------------------|-----------|----------------|----|
| Gd ₂ O ₃ | 0.01 | 1.0 | 183 | >10 ¹⁴ | 29 | 99.9 | 0.33 | 良好 |
| | 0.10 | 1.0 | 193 | >10 ¹⁴ | 31 | 100.0 | 0.32 | 良好 |
| | 1.00 | 1.0 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| | 2.00 | 1.0 | 209 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| | 5.00 | 1.0 | 194 | >10 ¹⁴ | 34 | 100.0 | 0.39 | 良好 |
| Dy ₂ O ₃ | 0.01 | 1.0 | 187 | >10 ¹⁴ | 34 | 99.9 | 0.31 | 良好 |
| | 0.10 | 1.0 | 190 | >10 ¹⁴ | 35 | 99.9 | 0.32 | 良好 |
| | 1.00 | 1.0 | 215 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| | 2.00 | 1.0 | 218 | >10 ¹⁴ | 34 | 100.0 | 0.36 | 良好 |
| | 5.00 | 1.0 | 209 | >10 ¹⁴ | 32 | 100.0 | 0.35 | 良好 |
| Yb ₂ O ₃ | 0.01 | 1.0 | 182 | >10 ¹⁴ | 32 | 99.8 | 0.31 | 良好 |
| | 0.10 | 1.0 | 183 | >10 ¹⁴ | 34 | 99.9 | 0.31 | 良好 |
| | 1.00 | 1.0 | 194 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| | 2.00 | 1.0 | 201 | >10 ¹⁴ | 36 | 100.0 | 0.36 | 良好 |
| | 5.00 | 1.0 | 202 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| CeO ₂ La ₂ O ₃ | 0.80 0.90 | 1.0 | 230 | >10 ¹⁴ | 34 | 100.0 | 0.36 | 良好 |
| La ₂ O ₃ Dy ₂ O ₃ | 0.50 1.00 | 1.0 | 231 | >10 ¹⁴ | 37 | 100.0 | 0.37 | 良好 |
| Yb ₂ O ₃ Nd ₂ O ₃ | 0.50 0.50 | 1.0 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.37 | 良好 |
| CeO ₂ La ₂ O ₃ Nd ₂ O ₃ | 0.50 0.50 0.50 | 1.0 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.38 | 良好 |

第 4 表

| No. | Y ₂ O ₃ 重量部 | B 重量部 | 添加剤 | | 熱伝導率 W/mK | 熱膨張係 10 ⁻⁶ /m | 強度 kg/mm ² | 相対密度 % | 表面粗度 Ra (μ m) | 外觀 |
|-----|--------------------------------------|----------|--------------------------------|------|--------------|-----------------------------|--------------------------|-----------|--------------------------|----|
| | | | 透 | 加 | | | | | | |
| 1 | 2.0 | 0.50 | Li ₂ O | 0.50 | 182 | >10 ⁻⁴ | 35 | 100.0 | 0.31 | 良好 |
| 2 | 2.0 | 0.50 | Li ₂ O | 1.00 | 194 | >10 ⁻⁴ | 34 | 100.0 | 0.30 | 良好 |
| 3 | 2.0 | 0.50 | Na ₂ O | 0.50 | 183 | >10 ⁻⁴ | 32 | 100.0 | 0.32 | 良好 |
| 4 | 2.0 | 0.50 | Na ₂ O | 1.00 | 190 | >10 ⁻⁴ | 34 | 100.0 | 0.32 | 良好 |
| 5 | 2.0 | 0.50 | K ₂ O | 0.50 | 175 | >10 ⁻⁴ | 35 | 100.0 | 0.31 | 良好 |
| 6 | 2.0 | 0.50 | K ₂ O | 1.00 | 178 | >10 ⁻⁴ | 38 | 100.0 | 0.33 | 良好 |
| 7 | 2.0 | 0.50 | B ₂ O ₃ | 0.50 | 202 | >10 ⁻⁴ | 38 | 100.0 | 0.31 | 良好 |
| 8 | 2.0 | 0.50 | B ₂ O ₃ | 1.00 | 205 | >10 ⁻⁴ | 36 | 100.0 | 0.30 | 良好 |
| 9 | 2.0 | 0.50 | SiO ₂ | 0.50 | 178 | >10 ⁻⁴ | 37 | 100.0 | 0.33 | 良好 |
| 10 | 2.0 | 0.50 | SiO ₂ | 1.00 | 177 | >10 ⁻⁴ | 32 | 100.0 | 0.29 | 良好 |
| 11 | 2.0 | 0.50 | GeO ₂ | 0.50 | 181 | >10 ⁻⁴ | 40 | 100.0 | 0.32 | 良好 |
| 12 | 2.0 | 0.50 | GeO ₂ | 1.00 | 189 | >10 ⁻⁴ | 31 | 100.0 | 0.34 | 良好 |
| 13 | 2.0 | 0.50 | As ₂ O ₃ | 0.50 | 190 | >10 ⁻⁴ | 36 | 100.0 | 0.33 | 良好 |
| 14 | 2.0 | 0.50 | As ₂ O ₃ | 1.00 | 192 | >10 ⁻⁴ | 37 | 100.0 | 0.31 | 良好 |
| 15 | 2.0 | 0.50 | P ₂ O ₅ | 0.50 | 193 | >10 ⁻⁴ | 35 | 100.0 | 0.30 | 良好 |
| 16 | 2.0 | 0.50 | P ₂ O ₅ | 1.00 | 195 | >10 ⁻⁴ | 31 | 100.0 | 0.29 | 良好 |
| 17 | 2.0 | 1.00 | Li ₂ O | 0.50 | 205 | >10 ⁻⁴ | 39 | 100.0 | 0.34 | 良好 |
| 18 | 2.0 | 1.00 | Li ₂ O | 1.00 | 210 | >10 ⁻⁴ | 31 | 100.0 | 0.33 | 良好 |
| 19 | 2.0 | 1.00 | Na ₂ O | 0.50 | 201 | >10 ⁻⁴ | 31 | 100.0 | 0.35 | 良好 |
| 20 | 2.0 | 1.00 | Na ₂ O | 1.00 | 198 | >10 ⁻⁴ | 32 | 100.0 | 0.34 | 良好 |
| 21 | 2.0 | 1.00 | K ₂ O | 0.50 | 205 | >10 ⁻⁴ | 37 | 100.0 | 0.36 | 良好 |
| 22 | 2.0 | 1.00 | K ₂ O | 1.00 | 210 | >10 ⁻⁴ | 36 | 100.0 | 0.36 | 良好 |
| 23 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | 223 | >10 ⁻⁴ | 32 | 100.0 | 0.38 | 良好 |
| 24 | 2.0 | 1.00 | B ₂ O ₃ | 1.00 | 228 | >10 ⁻⁴ | 33 | 100.0 | 0.38 | 良好 |
| 25 | 2.0 | 1.00 | SiO ₂ | 0.50 | 201 | >10 ⁻⁴ | 31 | 100.0 | 0.37 | 良好 |
| 26 | 2.0 | 1.00 | SiO ₂ | 1.00 | 204 | >10 ⁻⁴ | 32 | 100.0 | 0.32 | 良好 |
| 27 | 2.0 | 1.00 | GeO ₂ | 0.50 | 204 | >10 ⁻⁴ | 30 | 100.0 | 0.34 | 良好 |
| 28 | 2.0 | 1.00 | GeO ₂ | 1.00 | 209 | >10 ⁻⁴ | 37 | 100.0 | 0.36 | 良好 |
| 29 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | 198 | >10 ⁻⁴ | 37 | 100.0 | 0.39 | 良好 |
| 30 | 2.0 | 1.00 | As ₂ O ₃ | 1.00 | 194 | >10 ⁻⁴ | 36 | 100.0 | 0.38 | 良好 |
| 31 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | 213 | >10 ⁻⁴ | 34 | 100.0 | 0.37 | 良好 |
| 32 | 2.0 | 1.00 | P ₂ O ₅ | 1.00 | 217 | >10 ⁻⁴ | 32 | 100.0 | 0.37 | 良好 |
| 33 | 2.0 | 1.00 | Li ₂ O | 0.70 | 220 | >10 ⁻⁴ | 33 | 100.0 | 0.34 | 良好 |
| 34 | 2.0 | 1.00 | Li ₂ O | 0.50 | 221 | >10 ⁻⁴ | 38 | 100.0 | 0.32 | 良好 |
| 35 | 2.0 | 1.00 | K ₂ O | 0.50 | 221 | >10 ⁻⁴ | 36 | 100.0 | 0.34 | 良好 |
| 36 | 2.0 | 1.00 | K ₂ O | 0.80 | 229 | >10 ⁻⁴ | 34 | 100.0 | 0.29 | 良好 |

第 5 表

| No. | Y ₂ O ₃ 重量部 | B 重量部 | 添加剤 | | 熱伝導率 W/mK | 熱膨張係 10 ⁻⁶ /m | 強度 kg/mm ² | 相対密度 % | 表面粗度 Ra (μ m) | 外觀 |
|-----|--------------------------------------|----------|--------------------------------|------|--------------|-----------------------------|--------------------------|-----------|--------------------------|----|
| | | | 透 | 加 | | | | | | |
| 1 | 2.0 | 0.50 | LaB ₆ | 0.50 | 223 | >10 ⁻⁴ | 33 | 100.0 | 0.29 | 良好 |
| 2 | 2.0 | 0.50 | LaB ₆ | 1.00 | 235 | >10 ⁻⁴ | 34 | 100.0 | 0.31 | 良好 |
| 3 | 2.0 | 0.50 | CaB ₆ | 0.50 | 218 | >10 ⁻⁴ | 33 | 100.0 | 0.30 | 良好 |
| 4 | 2.0 | 0.50 | CaB ₆ | 1.00 | 221 | >10 ⁻⁴ | 35 | 100.0 | 0.31 | 良好 |
| 5 | 2.0 | 0.50 | Ca ₃ N ₂ | 0.50 | 234 | >10 ⁻⁴ | 34 | 100.0 | 0.29 | 良好 |
| 6 | 2.0 | 0.50 | Ca ₃ N ₂ | 1.00 | 240 | >10 ⁻⁴ | 37 | 100.0 | 0.30 | 良好 |
| 7 | 2.0 | 0.50 | AlP | 0.50 | 204 | >10 ⁻⁴ | 37 | 100.0 | 0.31 | 良好 |
| 8 | 2.0 | 0.50 | AlP | 1.00 | 207 | >10 ⁻⁴ | 38 | 100.0 | 0.32 | 良好 |
| 9 | 2.0 | 0.50 | LiMgP | 0.50 | 203 | >10 ⁻⁴ | 36 | 100.0 | 0.30 | 良好 |
| 10 | 2.0 | 0.50 | LiMgP | 1.00 | 206 | >10 ⁻⁴ | 35 | 100.0 | 0.34 | 良好 |
| 11 | 2.0 | 0.50 | CaS | 0.50 | 209 | >10 ⁻⁴ | 37 | 100.0 | 0.32 | 良好 |
| 12 | 2.0 | 0.50 | CaS | 1.00 | 211 | >10 ⁻⁴ | 36 | 100.0 | 0.33 | 良好 |
| 13 | 2.0 | 0.50 | BaS | 0.50 | 218 | >10 ⁻⁴ | 39 | 100.0 | 0.34 | 良好 |
| 14 | 2.0 | 0.50 | BaS | 1.00 | 214 | >10 ⁻⁴ | 32 | 100.0 | 0.33 | 良好 |
| 15 | 2.0 | 0.50 | MoSi ₂ | 0.50 | 195 | >10 ⁻⁴ | 33 | 100.0 | 0.32 | 良好 |
| 16 | 2.0 | 0.50 | MoSi ₂ | 1.00 | 201 | >10 ⁻⁴ | 32 | 100.0 | 0.31 | 良好 |
| 17 | 2.0 | 0.50 | CaH ₂ | 0.50 | 234 | >10 ⁻⁴ | 40 | 100.0 | 0.30 | 良好 |
| 18 | 2.0 | 0.50 | CaH ₂ | 1.00 | 236 | >10 ⁻⁴ | 38 | 100.0 | 0.34 | 良好 |
| 19 | 2.0 | 0.50 | LiAlH ₄ | 0.50 | 230 | >10 ⁻⁴ | 32 | 100.0 | 0.35 | 良好 |
| 20 | 2.0 | 0.50 | LiAlH ₄ | 1.00 | 239 | >10 ⁻⁴ | 36 | 100.0 | 0.33 | 良好 |
| 21 | 2.0 | 1.00 | LaB ₆ | 0.50 | 233 | >10 ⁻⁴ | 35 | 100.0 | 0.36 | 良好 |
| 22 | 2.0 | 1.00 | CaB ₆ | 0.50 | 222 | >10 ⁻⁴ | 33 | 100.0 | 0.34 | 良好 |
| 23 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | 238 | >10 ⁻⁴ | 39 | 100.0 | 0.36 | 良好 |
| 24 | 2.0 | 1.00 | AlP | 0.50 | 210 | >10 ⁻⁴ | 34 | 100.0 | 0.36 | 良好 |
| 25 | 2.0 | 1.00 | LiMgP | 0.50 | 211 | >10 ⁻⁴ | 37 | 100.0 | 0.35 | 良好 |
| 26 | 2.0 | 1.00 | CaS | 0.50 | 212 | >10 ⁻⁴ | 36 | 100.0 | 0.38 | 良好 |
| 27 | 2.0 | 1.00 | BaS | 0.50 | 225 | >10 ⁻⁴ | 34 | 100.0 | 0.37 | 良好 |
| 28 | 2.0 | 1.00 | MoSi ₂ | 0.50 | 196 | >10 ⁻⁴ | 36 | 100.0 | 0.38 | 良好 |
| 29 | 2.0 | 1.00 | MoSi ₂ | 1.00 | 203 | >10 ⁻⁴ | 34 | 100.0 | 0.34 | 良好 |
| 30 | 2.0 | 1.00 | CaH ₂ | 0.50 | 240 | >10 ⁻⁴ | 35 | 100.0 | 0.38 | 良好 |
| 31 | 2.0 | 1.00 | CaH ₂ | 1.00 | 245 | >10 ⁻⁴ | 37 | 100.0 | 0.35 | 良好 |
| 32 | 2.0 | 1.00 | LiAlH ₄ | 0.50 | 236 | >10 ⁻⁴ | 38 | 100.0 | 0.34 | 良好 |
| 33 | 2.0 | 1.00 | LiAlH ₄ | 1.00 | 244 | >10 ⁻⁴ | 35 | 100.0 | 0.33 | 良好 |
| 34 | 2.0 | 1.00 | LiAlH ₄ | 0.50 | 246 | >10 ⁻⁴ | 33 | 100.0 | 0.28 | 良好 |
| 35 | 2.0 | 1.00 | CaB ₆ | 0.50 | 241 | >10 ⁻⁴ | 38 | 100.0 | 0.34 | 良好 |
| 36 | 2.0 | 1.00 | Ca ₃ N ₂ | 1.00 | 239 | >10 ⁻⁴ | 36 | 100.0 | 0.38 | 良好 |
| 37 | 2.0 | 1.00 | CaS | 0.50 | 244 | >10 ⁻⁴ | 35 | 100.0 | 0.36 | 良好 |

第 6 表 - 1

| 第 6 表 - 1 | | | | | | | | | | | | |
|-----------|--------------------------------------|----------|--------------------------------|------|--------------------------------|--------------|-------------|--------------------------|-----------|--------------------------------|------|----|
| No. | Y ₂ O ₃ 重量部 | B 重量部 | 添 加 剤 | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相対密度 % | 表面粗度 R _a (μm) | 外觀 | |
| | | | | 重量部 | 重量部 | | | | | | | |
| 1 | 2.0 | 1.00 | LaBe | 0.50 | Li ₂ O | 0.20 | 226 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 2 | 2.0 | 1.00 | LaBe | 0.50 | K ₂ O | 0.10 | 227 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 3 | 2.0 | 1.00 | LaBe | 0.50 | B ₂ O ₃ | 0.50 | 219 | >10 ¹⁴ | 36 | 100.0 | 0.31 | 良好 |
| 4 | 2.0 | 1.00 | LaBe | 0.50 | SiO ₂ | 0.30 | 220 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 5 | 2.0 | 1.00 | LaBe | 0.50 | GeO ₂ | 0.10 | 223 | >10 ¹⁴ | 40 | 100.0 | 0.30 | 良好 |
| 6 | 2.0 | 1.00 | LaBe | 0.50 | P ₂ O ₅ | 0.20 | 231 | >10 ¹⁴ | 38 | 100.0 | 0.34 | 良好 |
| 7 | 2.0 | 1.00 | LaBe | 1.00 | As ₂ O ₅ | 0.10 | 233 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 |
| 8 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | Li ₂ O | 0.20 | 232 | >10 ¹⁴ | 33 | 100.0 | 0.23 | 良好 |
| 9 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | K ₂ O | 0.10 | 231 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 10 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | B ₂ O ₃ | 0.50 | 228 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 11 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | SiO ₂ | 0.30 | 232 | >10 ¹⁴ | 35 | 100.0 | 0.34 | 良好 |
| 12 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | GeO ₂ | 0.10 | 229 | >10 ¹⁴ | 36 | 100.0 | 0.31 | 良好 |
| 13 | 2.0 | 1.00 | Ca ₃ N ₂ | 0.50 | P ₂ O ₅ | 0.20 | 219 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 14 | 2.0 | 1.00 | Ca ₃ N ₂ | 1.00 | As ₂ O ₅ | 0.10 | 223 | >10 ¹⁴ | 34 | 100.0 | 0.29 | 良好 |
| 15 | 2.0 | 1.00 | CaS | 0.50 | Li ₂ O | 0.20 | 224 | >10 ¹⁴ | 31 | 100.0 | 0.31 | 良好 |
| 16 | 2.0 | 1.00 | CaS | 0.50 | K ₂ O | 0.10 | 221 | >10 ¹⁴ | 32 | 100.0 | 0.33 | 良好 |
| 17 | 2.0 | 1.00 | CaS | 0.50 | B ₂ O ₃ | 0.50 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.35 | 良好 |
| 18 | 2.0 | 1.00 | CaS | 0.50 | SiO ₂ | 0.30 | 219 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 19 | 2.0 | 1.00 | CaS | 0.50 | GeO ₂ | 0.10 | 219 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 20 | 2.0 | 1.00 | CaS | 0.50 | P ₂ O ₅ | 0.20 | 218 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 21 | 2.0 | 1.00 | CaS | 0.50 | As ₂ O ₅ | 0.10 | 221 | >10 ¹⁴ | 32 | 100.0 | 0.33 | 良好 |
| 22 | 2.0 | 1.00 | MoSi ₂ | 0.50 | Li ₂ O | 0.20 | 204 | >10 ¹⁴ | 36 | 100.0 | 0.34 | 良好 |
| 23 | 2.0 | 1.00 | MoSi ₂ | 0.50 | K ₂ O | 0.10 | 207 | >10 ¹⁴ | 31 | 100.0 | 0.34 | 良好 |
| 24 | 2.0 | 1.00 | MoSi ₂ | 0.50 | B ₂ O ₃ | 0.50 | 201 | >10 ¹⁴ | 41 | 100.0 | 0.33 | 良好 |
| 25 | 2.0 | 1.00 | MoSi ₂ | 0.50 | SiO ₂ | 0.30 | 203 | >10 ¹⁴ | 40 | 100.0 | 0.32 | 良好 |
| 26 | 2.0 | 1.00 | MoSi ₂ | 0.50 | GeO ₂ | 0.10 | 203 | >10 ¹⁴ | 39 | 100.0 | 0.37 | 良好 |
| 27 | 2.0 | 1.00 | MoSi ₂ | 0.50 | P ₂ O ₅ | 0.20 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.35 | 良好 |
| 28 | 2.0 | 1.00 | MoSi ₂ | 1.00 | As ₂ O ₅ | 0.10 | 207 | >10 ¹⁴ | 32 | 100.0 | 0.34 | 良好 |

第 6 表 - 2

| No. | Y ₂ O ₃ 重量部 | B 重量部 | 添 加 剤 | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相対密度 % | 表面粗度 R _a (μm) | 外觀 | |
|-----|--------------------------------------|----------|---|----------------------|--|----------------------|-------------|--------------------------|-----------|--------------------------------|------|----|
| | | | | 重量部 | 重量部 | | | | | | | |
| 29 | 2.0 | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 0.20 | 233 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 30 | 2.0 | 1.00 | CaH ₂ | 0.50 | K ₂ O | 0.10 | 231 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 31 | 2.0 | 1.00 | CaH ₂ | 0.50 | B ₂ O ₃ | 0.50 | 239 | >10 ¹⁴ | 38 | 100.0 | 0.34 | 良好 |
| 32 | 2.0 | 1.00 | CaH ₂ | 0.50 | SiO ₂ | 0.30 | 220 | >10 ¹⁴ | 35 | 100.0 | 0.35 | 良好 |
| 33 | 2.0 | 1.00 | CaH ₂ | 0.50 | GeO ₂ | 0.10 | 232 | >10 ¹⁴ | 39 | 100.0 | 0.31 | 良好 |
| 34 | 2.0 | 1.00 | CaH ₂ | 0.50 | P ₂ O ₅ | 0.20 | 233 | >10 ¹⁴ | 31 | 100.0 | 0.35 | 良好 |
| 35 | 2.0 | 1.00 | CaH ₂ | 1.00 | As ₂ O ₅ | 0.10 | 230 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 |
| 36 | 2.0 | 1.00 | LaBe CaH ₂ | 0.20 0.30 | B ₂ O ₃ | 0.20 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.36 | 良好 |
| 37 | 2.0 | 1.00 | LaBe | 0.50 | B ₂ O ₃ Li ₂ O | 0.20 0.30 | 242 | >10 ¹⁴ | 36 | 100.0 | 0.39 | 良好 |
| 38 | 2.0 | 1.00 | CaS CaH ₂ | 0.20 0.30 | B ₂ O ₃ P ₂ O ₅ | 0.20 0.20 | 239 | >10 ¹⁴ | 37 | 100.0 | 0.39 | 良好 |
| 39 | 2.0 | 1.00 | CaS CaH ₂ | 0.20 0.30 | B ₂ O ₃ P ₂ O ₅ | 0.20 0.20 | 243 | >10 ¹⁴ | 40 | 100.0 | 0.38 | 良好 |
| 40 | 2.0 | 1.00 | CaS CaH ₂ Ca ₃ N ₂ | 0.20 0.20 0.10 | B ₂ O ₃ SiO ₂ Na ₂ O | 0.20 0.20 1.00 | 245 | >10 ¹⁴ | 37 | 100.0 | 0.34 | 良好 |

第 7 表

| No. | Y ₂ O ₃ 濃度 % | B ₂ O ₃ 濃度 % | 添 加 劑 | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相对密度 % | 表面粗度 Ra (μm) | 外觀 |
|-----|--|--|---|--------------|-------------------|--------------------------|-----------|--------------------|----|
| 1 | 2.0 | 0.50 | Al ₂ O ₃ | 2.02 | >10 ¹⁴ | 35 | 100.0 | 0.30 | 良好 |
| 2 | 2.0 | 0.50 | Al ₂ O ₃ | 2.06 | >10 ¹⁴ | 33 | 100.0 | 0.31 | 良好 |
| 3 | 2.0 | 0.50 | Ga ₂ O ₃ | 2.03 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 4 | 2.0 | 0.50 | Ga ₂ O ₃ | 2.05 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 5 | 2.0 | 0.50 | In ₂ O ₃ | 2.11 | >10 ¹⁴ | 37 | 100.0 | 0.31 | 良好 |
| 6 | 2.0 | 0.50 | In ₂ O ₃ | 2.06 | >10 ¹⁴ | 33 | 100.0 | 0.29 | 良好 |
| 7 | 2.0 | 0.50 | WO ₃ | 2.02 | >10 ¹⁴ | 35 | 100.0 | 0.28 | 良好 |
| 8 | 2.0 | 0.50 | WO ₃ | 2.05 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 |
| 9 | 2.0 | 0.50 | Bi ₂ O ₃ | 2.10 | >10 ¹⁴ | 34 | 100.0 | 0.29 | 良好 |
| 10 | 2.0 | 0.50 | Bi ₂ O ₃ | 2.08 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 |
| 11 | 2.0 | 0.50 | PbO | 2.02 | >10 ¹⁴ | 33 | 100.0 | 0.31 | 良好 |
| 12 | 2.0 | 0.50 | PbO | 2.03 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 13 | 2.0 | 0.50 | Sb ₂ O ₃ | 2.10 | >10 ¹⁴ | 37 | 100.0 | 0.33 | 良好 |
| 14 | 2.0 | 0.50 | Sb ₂ O ₃ | 2.12 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 15 | 2.0 | 0.50 | CdO | 2.16 | >10 ¹⁴ | 35 | 100.0 | 0.31 | 良好 |
| 16 | 2.0 | 0.50 | CdO | 2.11 | >10 ¹⁴ | 35 | 100.0 | 0.34 | 良好 |
| 17 | 2.0 | 0.50 | ZnO | 2.07 | >10 ¹⁴ | 36 | 100.0 | 0.33 | 良好 |
| 18 | 2.0 | 0.50 | ZnO | 2.09 | >10 ¹⁴ | 32 | 100.0 | 0.35 | 良好 |
| 19 | 2.0 | 1.00 | Al ₂ O ₃ | 2.32 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 20 | 2.0 | 1.00 | Al ₂ O ₃ | 2.33 | >10 ¹⁴ | 35 | 100.0 | 0.36 | 良好 |
| 21 | 2.0 | 1.00 | Ga ₂ O ₃ | 2.21 | >10 ¹⁴ | 36 | 100.0 | 0.37 | 良好 |
| 22 | 2.0 | 1.00 | Ga ₂ O ₃ | 2.23 | >10 ¹⁴ | 34 | 100.0 | 0.36 | 良好 |
| 23 | 2.0 | 1.00 | In ₂ O ₃ | 2.13 | >10 ¹⁴ | 37 | 100.0 | 0.36 | 良好 |
| 24 | 2.0 | 1.00 | In ₂ O ₃ | 2.21 | >10 ¹⁴ | 38 | 100.0 | 0.34 | 良好 |
| 25 | 2.0 | 1.00 | WO ₃ | 2.40 | >10 ¹⁴ | 31 | 100.0 | 0.36 | 良好 |
| 26 | 2.0 | 1.00 | WO ₃ | 2.22 | >10 ¹⁴ | 38 | 100.0 | 0.37 | 良好 |
| 27 | 2.0 | 1.00 | Bi ₂ O ₃ | 2.31 | >10 ¹⁴ | 37 | 100.0 | 0.36 | 良好 |
| 28 | 2.0 | 1.00 | Bi ₂ O ₃ | 2.32 | >10 ¹⁴ | 33 | 100.0 | 0.35 | 良好 |
| 29 | 2.0 | 1.00 | PbO | 2.37 | >10 ¹⁴ | 36 | 100.0 | 0.38 | 良好 |
| 30 | 2.0 | 1.00 | PbO | 2.36 | >10 ¹⁴ | 35 | 100.0 | 0.40 | 良好 |
| 31 | 2.0 | 1.00 | Sb ₂ O ₃ | 2.38 | >10 ¹⁴ | 31 | 100.0 | 0.36 | 良好 |
| 32 | 2.0 | 1.00 | Sb ₂ O ₃ | 2.33 | >10 ¹⁴ | 32 | 100.0 | 0.36 | 良好 |
| 33 | 2.0 | 1.00 | CdO | 2.32 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 34 | 2.0 | 1.00 | CdO | 2.22 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 |
| 35 | 2.0 | 1.00 | ZnO | 2.13 | >10 ¹⁴ | 35 | 100.0 | 0.37 | 良好 |
| 36 | 2.0 | 1.00 | ZnO | 2.15 | >10 ¹⁴ | 32 | 100.0 | 0.38 | 良好 |
| 37 | 2.0 | 1.00 | Al ₂ O ₃ In ₂ O ₃ | 2.37 | >10 ¹⁴ | 39 | 100.0 | 0.35 | 良好 |
| 38 | 2.0 | 1.00 | Al ₂ O ₃ WO ₃ | 2.38 | >10 ¹⁴ | 37 | 100.0 | 0.34 | 良好 |
| 39 | 2.0 | 1.00 | CdO Sb ₂ O ₃ | 2.40 | >10 ¹⁴ | 34 | 100.0 | 0.37 | 良好 |
| 40 | 2.0 | 1.00 | Al ₂ O ₃ In ₂ O ₃ PbO | 2.32 | >10 ¹⁴ | 35 | 100.0 | 0.35 | 良好 |

第 8 表 - 1

| 第 8 表 - 1 | | | 添 加 剤 | | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相对密度 % | 表面粗度 Ra (μm) | 外觀 |
|-----------|--------------------------------------|-------------------------|--------------------------------|------|--------------------------------|------|--------------|-------------------|--------------------------|-----------|--------------------|----|
| No. | Y ₂ O ₃ 重量部 | ZrO ₂ 重量部 | | 重量部 | | 重量部 | | | | | | |
| 1 | 2.0 | 1.00 | Li ₂ O | 0.50 | Al ₂ O ₃ | 0.20 | 213 | >10 ¹⁴ | 32 | 100.0 | 0.31 | 良好 |
| 2 | 2.0 | 1.00 | Li ₂ O | 0.50 | Ga ₂ O ₃ | 0.10 | 221 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 3 | 2.0 | 1.00 | Li ₂ O | 0.50 | In ₂ O ₃ | 0.50 | 223 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 4 | 2.0 | 1.00 | Li ₂ O | 0.50 | WO ₃ | 0.30 | 221 | >10 ¹⁴ | 34 | 100.0 | 0.31 | 良好 |
| 5 | 2.0 | 1.00 | Li ₂ O | 0.50 | Bi ₂ O ₃ | 0.10 | 219 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 6 | 2.0 | 1.00 | Li ₂ O | 0.50 | PbO | 0.20 | 223 | >10 ¹⁴ | 36 | 100.0 | 0.33 | 良好 |
| 7 | 2.0 | 1.00 | Li ₂ O | 1.00 | Sb ₂ O ₃ | 0.10 | 224 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 8 | 2.0 | 1.00 | Li ₂ O | 1.00 | CdO | 0.30 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.35 | 良好 |
| 9 | 2.0 | 1.00 | Li ₂ O | 1.00 | ZnO | 0.30 | 214 | >10 ¹⁴ | 33 | 100.0 | 0.37 | 良好 |
| 10 | 2.0 | 1.00 | Na ₂ O | 0.50 | Al ₂ O ₃ | 0.20 | 223 | >10 ¹⁴ | 32 | 100.0 | 0.33 | 良好 |
| 11 | 2.0 | 1.00 | Na ₂ O | 0.50 | Ga ₂ O ₃ | 0.10 | 220 | >10 ¹⁴ | 34 | 100.0 | 0.31 | 良好 |
| 12 | 2.0 | 1.00 | Na ₂ O | 0.50 | In ₂ O ₃ | 0.50 | 219 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 13 | 2.0 | 1.00 | Na ₂ O | 0.50 | WO ₃ | 0.30 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 14 | 2.0 | 1.00 | Na ₂ O | 0.50 | Bi ₂ O ₃ | 0.10 | 225 | >10 ¹⁴ | 34 | 100.0 | 2.33 | 良好 |
| 15 | 2.0 | 1.00 | Na ₂ O | 0.50 | PbO | 0.20 | 210 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 |
| 16 | 2.0 | 1.00 | Na ₂ O | 1.00 | Sb ₂ O ₃ | 0.10 | 223 | >10 ¹⁴ | 35 | 100.0 | 0.31 | 良好 |
| 17 | 2.0 | 1.00 | Na ₂ O | 0.50 | CdO | 0.30 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 18 | 2.0 | 1.00 | Na ₂ O | 1.00 | ZnO | 0.30 | 217 | >10 ¹⁴ | 33 | 100.0 | 0.29 | 良好 |
| 19 | 2.0 | 1.00 | K ₂ O | 0.50 | Al ₂ O ₃ | 0.20 | 221 | >10 ¹⁴ | 33 | 100.0 | 0.30 | 良好 |
| 20 | 2.0 | 1.00 | K ₂ O | 0.50 | Ga ₂ O ₃ | 0.10 | 214 | >10 ¹⁴ | 31 | 100.0 | 0.31 | 良好 |
| 21 | 2.0 | 1.00 | K ₂ O | 0.50 | In ₂ O ₃ | 0.50 | 220 | >10 ¹⁴ | 35 | 100.0 | 0.32 | 良好 |
| 22 | 2.0 | 1.00 | K ₂ O | 0.50 | WO ₃ | 0.30 | 210 | >10 ¹⁴ | 33 | 100.0 | 0.38 | 良好 |
| 23 | 2.0 | 1.00 | K ₂ O | 0.50 | Bi ₂ O ₃ | 0.10 | 212 | >10 ¹⁴ | 32 | 100.0 | 0.37 | 良好 |
| 24 | 2.0 | 1.00 | K ₂ O | 0.50 | PbO | 0.20 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 25 | 2.0 | 1.00 | K ₂ O | 1.00 | Sb ₂ O ₃ | 0.10 | 218 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 26 | 2.0 | 1.00 | K ₂ O | 0.50 | CdO | 0.30 | 217 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 27 | 2.0 | 1.00 | K ₂ O | 1.00 | ZnO | 0.30 | 222 | >10 ¹⁴ | 34 | 100.0 | 0.38 | 良好 |
| 28 | 2.0 | 1.00 | Bi ₂ O ₃ | 0.50 | Al ₂ O ₃ | 0.20 | 201 | >10 ¹⁴ | 34 | 100.0 | 0.40 | 良好 |
| 29 | 2.0 | 1.00 | Bi ₂ O ₃ | 0.50 | Ga ₂ O ₃ | 0.10 | 203 | >10 ¹⁴ | 33 | 100.0 | 0.42 | 良好 |

第 8 表 - 2

| 第 8 表 - 2 | | | | | | | | | | | | |
|-----------|--------------------------------------|------------|--------------------------------|------|--------------------------------|--------------|-------------|---------------------------|-----------|--------------------------------|------|----|
| No. | Y ₂ O ₃ 重量部 | ZnO 重量部 | 添 加 剤 | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強 度 kg/mm ² | 相対密度 % | 表面粗度 R _a (μm) | 外觀 | |
| | | | 重量部 | | 重量部 | | | | | | | |
| 30 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | In ₂ O ₃ | 0.50 | 202 | >10 ¹⁴ | 38 | 100.0 | 0.40 | 良好 |
| 31 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | WO ₃ | 0.30 | 203 | >10 ¹⁴ | 32 | 100.0 | 0.39 | 良好 |
| 32 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | Bi ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 31 | 100.0 | 0.38 | 良好 |
| 33 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | PbO | 0.20 | 204 | >10 ¹⁴ | 32 | 100.0 | 0.37 | 良好 |
| 34 | 2.0 | 1.00 | B ₂ O ₃ | 1.00 | Sb ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 33 | 100.0 | 0.36 | 良好 |
| 35 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | CdO | 0.30 | 203 | >10 ¹⁴ | 33 | 100.0 | 0.38 | 良好 |
| 36 | 2.0 | 1.00 | B ₂ O ₃ | 1.00 | ZnO | 0.30 | 204 | >10 ¹⁴ | 32 | 100.0 | 0.35 | 良好 |
| 37 | 2.0 | 1.00 | SiO ₂ | 0.50 | Ag ₂ O ₃ | 0.20 | 240 | >10 ¹⁴ | 31 | 100.0 | 0.32 | 良好 |
| 38 | 2.0 | 1.00 | SiO ₂ | 0.50 | Ga ₂ O ₃ | 0.10 | 238 | >10 ¹⁴ | 32 | 100.0 | 0.31 | 良好 |
| 39 | 2.0 | 1.00 | SiO ₂ | 0.50 | In ₂ O ₃ | 0.50 | 239 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 40 | 2.0 | 1.00 | SiO ₂ | 0.50 | WO ₃ | 0.30 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.30 | 良好 |
| 41 | 2.0 | 1.00 | SiO ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 38 | 100.0 | 0.29 | 良好 |
| 42 | 2.0 | 1.00 | SiO ₂ | 0.50 | PbO | 0.20 | 231 | >10 ¹⁴ | 33 | 100.0 | 0.29 | 良好 |
| 43 | 2.0 | 1.00 | SiO ₂ | 1.00 | Sb ₂ O ₃ | 0.10 | 238 | >10 ¹⁴ | 34 | 100.0 | 0.30 | 良好 |
| 44 | 2.0 | 1.00 | SiO ₂ | 0.50 | CdO | 0.30 | 237 | >10 ¹⁴ | 33 | 100.0 | 0.31 | 良好 |
| 45 | 2.0 | 1.00 | SiO ₂ | 1.00 | ZnO | 0.30 | 233 | >10 ¹⁴ | 32 | 100.0 | 0.32 | 良好 |
| 46 | 2.0 | 1.00 | GeO ₂ | 0.50 | Ag ₂ O ₃ | 0.20 | 221 | >10 ¹⁴ | 32 | 100.0 | 0.29 | 良好 |
| 47 | 2.0 | 1.00 | GeO ₂ | 0.50 | Ga ₂ O ₃ | 0.10 | 223 | >10 ¹⁴ | 31 | 100.0 | 0.30 | 良好 |
| 48 | 2.0 | 1.00 | GeO ₂ | 0.50 | In ₂ O ₃ | 0.50 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.29 | 良好 |
| 49 | 2.0 | 1.00 | GeO ₂ | 0.50 | WO ₃ | 0.30 | 219 | >10 ¹⁴ | 33 | 100.0 | 0.31 | 良好 |
| 50 | 2.0 | 1.00 | GeO ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 233 | >10 ¹⁴ | 35 | 100.0 | 0.31 | 良好 |
| 51 | 2.0 | 1.00 | GeO ₂ | 0.50 | PbO | 0.20 | 219 | >10 ¹⁴ | 37 | 100.0 | 0.32 | 良好 |
| 52 | 2.0 | 1.00 | GeO ₂ | 1.00 | Sb ₂ O ₃ | 0.10 | 209 | >10 ¹⁴ | 38 | 100.0 | 0.31 | 良好 |
| 53 | 2.0 | 1.00 | GeO ₂ | 0.50 | CdO | 0.30 | 212 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 |
| 54 | 2.0 | 1.00 | GeO ₂ | 1.00 | ZnO | 0.30 | 221 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 55 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | Ag ₂ O ₃ | 0.20 | 241 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 |
| 56 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | Ga ₂ O ₃ | 0.10 | 239 | >10 ¹⁴ | 31 | 100.0 | 0.30 | 良好 |
| 57 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | In ₂ O ₃ | 0.50 | 237 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 58 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | WO ₃ | 0.30 | 239 | >10 ¹⁴ | 34 | 100.0 | 232 | 良好 |

第 8 表 - 3

| 第 8 表 - 3 | | | | | | | | | | | | |
|-----------|--------------------------------------|-----------|--|----------------------|---|----------------------|-------------|--------------------------|-----------|--------------------|------|-----|
| No. | Y ₂ O ₃ 重量部 | Zn 重量部 | 添 加 剤 | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 強度 kg/mm ² | 相對密度 % | 表面粗度 Ra (μm) | 外觀 | |
| | | | | 重量部 | | | | | | | | 重量部 |
| 59 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | Bi ₂ O ₃ | 0.10 | 237 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 60 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | PbO | 0.20 | 233 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 61 | 2.0 | 1.00 | As ₂ O ₃ | 1.00 | Sb ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 32 | 100.0 | 0.31 | 良好 |
| 62 | 2.0 | 1.00 | As ₂ O ₃ | 0.50 | CdO | 0.30 | 238 | >10 ¹⁴ | 35 | 100.0 | 0.32 | 良好 |
| 63 | 2.0 | 1.00 | As ₂ O ₃ | 1.00 | ZnO | 0.30 | 234 | >10 ¹⁴ | 31 | 100.0 | 0.32 | 良好 |
| 64 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | Ag ₂ O ₃ | 0.20 | 239 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 65 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | Ga ₂ O ₃ | 0.10 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.35 | 良好 |
| 66 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | In ₂ O ₃ | 0.50 | 234 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 67 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | WO ₃ | 0.30 | 239 | >10 ¹⁴ | 39 | 100.0 | 0.32 | 良好 |
| 68 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | Bi ₂ O ₃ | 0.10 | 234 | >10 ¹⁴ | 35 | 100.0 | 0.34 | 良好 |
| 69 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | PbO | 0.20 | 234 | >10 ¹⁴ | 33 | 100.0 | 0.29 | 良好 |
| 70 | 2.0 | 1.00 | P ₂ O ₅ | 1.00 | Sb ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 32 | 100.0 | 0.29 | 良好 |
| 71 | 2.0 | 1.00 | P ₂ O ₅ | 0.50 | CdO | 0.30 | 238 | >10 ¹⁴ | 31 | 100.0 | 0.32 | 良好 |
| 72 | 2.0 | 1.00 | P ₂ O ₅ | 1.00 | ZnO | 0.30 | 237 | >10 ¹⁴ | 30 | 100.0 | 0.34 | 良好 |
| 73 | 2.0 | 1.00 | Li ₂ O + R ₂ O ₃ | 0.20 0.30 | Ag ₂ O ₃ | 0.20 | 238 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 74 | 2.0 | 1.00 | B ₂ O ₃ | 0.50 | Ag ₂ O ₃ + In ₂ O ₃ | 0.20 0.30 | 237 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 75 | 2.0 | 1.00 | Na ₂ O + SiO ₂ | 0.10 0.30 | WO ₃ + Sb ₂ O ₃ | 0.20 0.20 | 240 | >10 ¹⁴ | 36 | 100.0 | 0.35 | 良好 |
| 76 | 2.0 | 1.00 | Li ₂ O + P ₂ O ₅ | 0.02 0.30 | CdO + ZnO | 0.20 0.20 | 241 | >10 ¹⁴ | 38 | 100.0 | 0.36 | 良好 |
| 76 | 2.0 | 1.00 | K ₂ O + As ₂ O ₃ + SiO ₂ | 0.01 0.01 0.05 | Ag ₂ O ₃ + CdO + PbO | 0.20 0.20 1.00 | 242 | >10 ¹⁴ | 35 | 100.0 | 0.37 | 良好 |

第 9 表 - 1

| No. | Y ₂ O ₃ 重量部 | Li 重量部 | 添 加 物 | | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 硬 度 kg/mm ² | 相対密度 % | 表面粗度 Ra (μm) | 外觀 |
|-----|--------------------------------------|-----------|--------------------------------|------|--------------------------------|------|--------------|-------------------|---------------------------|-----------|--------------------|----|
| | | | | 重量部 | | 重量部 | | | | | | |
| 1 | 2.0 | 1.00 | CaH ₆ | 0.50 | Al ₂ O ₃ | 0.20 | 221 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 |
| 2 | 2.0 | 1.00 | CaH ₆ | 0.50 | Ga ₂ O ₃ | 0.20 | 222 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 |
| 3 | 2.0 | 1.00 | CaH ₆ | 0.50 | In ₂ O ₃ | 0.20 | 219 | >10 ¹⁴ | 35 | 100.0 | 0.35 | 良好 |
| 4 | 2.0 | 1.00 | CaH ₆ | 0.50 | WO ₃ | 0.20 | 223 | >10 ¹⁴ | 38 | 100.0 | 0.36 | 良好 |
| 5 | 2.0 | 1.00 | CaDe | 0.50 | Bi ₂ O ₃ | 0.10 | 228 | >10 ¹⁴ | 40 | 100.0 | 0.34 | 良好 |
| 6 | 2.0 | 1.00 | CaDe | 0.50 | PbO | 0.10 | 220 | >10 ¹⁴ | 33 | 100.0 | 0.40 | 良好 |
| 7 | 2.0 | 1.00 | CaH ₆ | 0.50 | Sb ₂ O ₃ | 0.10 | 221 | >10 ¹⁴ | 37 | 100.0 | 0.37 | 良好 |
| 8 | 2.0 | 1.00 | CaDe | 0.50 | CdO | 0.30 | 218 | >10 ¹⁴ | 39 | 100.0 | 0.36 | 良好 |
| 9 | 2.0 | 1.00 | CaDe | 0.50 | ZnO | 0.30 | 232 | >10 ¹⁴ | 39 | 100.0 | 0.34 | 良好 |
| 10 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | Al ₂ O ₃ | 0.20 | 238 | >10 ¹⁴ | 32 | 100.0 | 0.35 | 良好 |
| 11 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | In ₂ O ₃ | 0.20 | 232 | >10 ¹⁴ | 34 | 100.0 | 0.31 | 良好 |
| 12 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | WO ₃ | 0.20 | 235 | >10 ¹⁴ | 35 | 100.0 | 0.39 | 良好 |
| 13 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 230 | >10 ¹⁴ | 33 | 100.0 | 0.29 | 良好 |
| 14 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | PbO | 0.10 | 225 | >10 ¹⁴ | 34 | 100.0 | 0.30 | 良好 |
| 15 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | Sb ₂ O ₃ | 0.10 | 230 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 16 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | CdO | 0.30 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 |
| 17 | 2.0 | 1.00 | Cu ₃ N ₂ | 0.50 | ZnO | 0.30 | 209 | >10 ¹⁴ | 33 | 100.0 | 0.32 | 良好 |
| 18 | 2.0 | 1.00 | H ₂ S | 0.50 | Al ₂ O ₃ | 0.20 | 232 | >10 ¹⁴ | 36 | 100.0 | 0.36 | 良好 |
| 19 | 2.0 | 1.00 | H ₂ S | 0.50 | WO ₃ | 0.20 | 220 | >10 ¹⁴ | 38 | 100.0 | 0.34 | 良好 |
| 20 | 2.0 | 1.00 | H ₂ S | 0.50 | Bi ₂ O ₃ | 0.10 | 217 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 |
| 21 | 2.0 | 1.00 | H ₂ S | 0.50 | PbO | 0.10 | 222 | >10 ¹⁴ | 36 | 100.0 | 0.34 | 良好 |
| 22 | 2.0 | 1.00 | H ₂ S | 0.50 | Sb ₂ O ₃ | 0.10 | 219 | >10 ¹⁴ | 36 | 100.0 | 0.31 | 良好 |
| 23 | 2.0 | 1.00 | H ₂ S | 0.50 | CdO | 0.30 | 209 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 24 | 2.0 | 1.00 | H ₂ S | 0.50 | ZnO | 0.30 | 237 | >10 ¹⁴ | 32 | 100.0 | 0.37 | 良好 |
| 25 | 2.0 | 1.00 | MnSi ₂ | 0.50 | Al ₂ O ₃ | 0.20 | 199 | >10 ¹⁴ | 35 | 100.0 | 0.37 | 良好 |
| 26 | 2.0 | 1.00 | MoSi ₂ | 0.50 | WO ₃ | 0.20 | 202 | >10 ¹⁴ | 41 | 100.0 | 0.38 | 良好 |
| 27 | 2.0 | 1.00 | MoSi ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 210 | >10 ¹⁴ | 31 | 100.0 | 0.37 | 良好 |
| 28 | 2.0 | 1.00 | MoSi ₂ | 0.50 | CdO | 0.30 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.35 | 良好 |

第 9 表 - 2

| No. | Y ₂ O ₃ 重量部 | Li 重量部 | 添 加 物 | | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 硬 度 kg/mm ² | 相対密度 % | 表面粗度 Ra (μm) | 外觀 |
|-----|--------------------------------------|-----------|---|----------------------|--|----------------------|--------------|-------------------|---------------------------|-----------|--------------------|----|
| | | | | 重量部 | | 重量部 | | | | | | |
| 29 | 2.0 | 1.00 | MoSi ₂ | 0.50 | ZnO | 0.30 | 207 | >10 ¹⁴ | 33 | 100.0 | 0.36 | 良好 |
| 30 | 2.0 | 1.00 | CaH ₂ | 0.50 | Al ₂ O ₃ | 0.20 | 240 | >10 ¹⁴ | 33 | 100.0 | 0.37 | 良好 |
| 31 | 2.0 | 1.00 | CaH ₂ | 0.50 | Ga ₂ O ₃ | 0.20 | 239 | >10 ¹⁴ | 36 | 100.0 | 0.34 | 良好 |
| 32 | 2.0 | 1.00 | CaH ₂ | 0.50 | In ₂ O ₃ | 0.20 | 235 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 |
| 33 | 2.0 | 1.00 | CaH ₂ | 0.50 | WO ₃ | 0.20 | 230 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 |
| 34 | 2.0 | 1.00 | CaH ₂ | 0.50 | Bi ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 35 | 2.0 | 1.00 | CaH ₂ | 0.50 | PbO | 0.10 | 200 | >10 ¹⁴ | 33 | 100.0 | 0.35 | 良好 |
| 36 | 2.0 | 1.00 | CaH ₂ | 0.50 | Sb ₂ O ₃ | 0.10 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 |
| 37 | 2.0 | 1.00 | CaH ₂ | 0.50 | CdO | 0.30 | 213 | >10 ¹⁴ | 34 | 100.0 | 0.31 | 良好 |
| 38 | 2.0 | 1.00 | CaH ₂ | 0.50 | ZnO | 0.30 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 |
| 39 | 2.0 | 1.00 | LaB ₆ + CaH ₂ | 0.20 0.30 | WO ₃ | 0.20 | 238 | >10 ¹⁴ | 36 | 100.0 | 0.35 | 良好 |
| 40 | 2.0 | 1.00 | LaB ₆ | 0.50 | Al ₂ O ₃ + CdO | 0.20 0.30 | 239 | >10 ¹⁴ | 37 | 100.0 | 0.36 | 良好 |
| 41 | 2.0 | 1.00 | ZnS + BaS | 0.20 0.30 | CdO + ZnO | 0.20 0.20 | 230 | >10 ¹⁴ | 40 | 100.0 | 0.36 | 良好 |
| 42 | 2.0 | 1.00 | CaS + CaH ₂ + Ca ₃ N ₂ | 0.20 0.20 0.10 | Sb ₂ O ₃ + PbO + ZnO | 0.20 0.20 1.00 | 244 | >10 ¹⁴ | 39 | 100.0 | 0.30 | 良好 |

第10表-1

| 添 加 物 | | | | | | | | | | | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 堆 積 kg/mm ² | 相対密度 % | 表面粗度 Ra (μm) | 外觀 |
|-------|--------------------------------------|----------|--------------------------------|------|--------------------------------|------|--------------------------------|------|-----|-------------------|----|-------|--------------|-------------|---------------------------|-----------|--------------------|----|
| No. | Y ₂ O ₃ wt% | B wt% | | wt% | | wt% | | wt% | | | | | | | | | | |
| 1 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | Li ₂ O | 0.20 | 223 | >10 ¹⁴ | 32 | 100.0 | 0.34 | 良好 | | | | |
| 2 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | K ₂ O | 0.20 | 224 | >10 ¹⁴ | 35 | 100.0 | 0.34 | 良好 | | | | |
| 3 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | B ₂ O ₃ | 0.20 | 232 | >10 ¹⁴ | 37 | 100.0 | 0.33 | 良好 | | | | |
| 4 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | SiO ₂ | 0.20 | 218 | >10 ¹⁴ | 35 | 100.0 | 0.34 | 良好 | | | | |
| 5 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | GeO ₂ | 0.20 | 220 | >10 ¹⁴ | 39 | 100.0 | 0.37 | 良好 | | | | |
| 6 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | P ₂ O ₅ | 0.20 | 220 | >10 ¹⁴ | 37 | 100.0 | 0.33 | 良好 | | | | |
| 7 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | LaB ₆ | 0.50 | As ₂ O ₅ | 0.20 | 218 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 | | | | |
| 8 | 2.0 | 0.20 | ZnO | 0.50 | Mg ₃ N ₂ | 2.00 | B ₂ O ₃ | 0.10 | 209 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 | | | | |
| 9 | 2.0 | 0.20 | ZnO | 0.50 | Ca ₃ N ₂ | 2.00 | B ₂ O ₃ | 0.10 | 210 | >10 ¹⁴ | 34 | 100.0 | 0.34 | 良好 | | | | |
| 10 | 2.0 | 0.20 | ZnO | 0.50 | LaB ₆ | 2.00 | B ₂ O ₃ | 0.10 | 233 | >10 ¹⁴ | 33 | 100.0 | 0.33 | 良好 | | | | |
| 11 | 2.0 | 0.20 | ZnO | 0.50 | CaB ₆ | 2.00 | B ₂ O ₃ | 0.10 | 239 | >10 ¹⁴ | 36 | 100.0 | 0.34 | 良好 | | | | |
| 12 | 2.0 | 0.20 | ZnO | 0.50 | CaS | 2.00 | B ₂ O ₃ | 0.10 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.33 | 良好 | | | | |
| 13 | 2.0 | 0.20 | ZnO | 0.50 | Na ₂ S | 2.00 | B ₂ O ₃ | 0.10 | 202 | >10 ¹⁴ | 35 | 100.0 | 0.25 | 良好 | | | | |
| 14 | 2.0 | 0.20 | ZnO | 0.50 | AlP | 2.00 | B ₂ O ₃ | 0.10 | 215 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 | | | | |
| 15 | 2.0 | 0.20 | ZnO | 0.50 | Ca ₃ P ₂ | 2.50 | B ₂ O ₃ | 0.10 | 232 | >10 ¹⁴ | 32 | 100.0 | 0.36 | 良好 | | | | |
| 16 | 2.0 | 0.20 | ZnO | 0.50 | MaSi ₂ | 2.50 | B ₂ O ₃ | 0.10 | 205 | >10 ¹⁴ | 31 | 100.0 | 0.35 | 良好 | | | | |
| 17 | 2.0 | 0.20 | ZnO | 0.50 | Zr ₂ Si | 2.00 | B ₂ O ₃ | 0.10 | 201 | >10 ¹⁴ | 33 | 100.0 | 0.35 | 良好 | | | | |
| 18 | 2.0 | 0.20 | ZnO | 0.50 | CaH ₂ | 2.00 | B ₂ O ₃ | 0.10 | 244 | >10 ¹⁴ | 34 | 100.0 | 0.33 | 良好 | | | | |
| 19 | 2.0 | 0.20 | ZnO | 0.50 | LiAlH ₄ | 2.00 | B ₂ O ₃ | 0.10 | 242 | >10 ¹⁴ | 35 | 100.0 | 0.35 | 良好 | | | | |
| 20 | 2.0 | 1.00 | Al ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 230 | >10 ¹⁴ | 36 | 100.0 | 0.32 | 良好 | | | | |
| 21 | 2.0 | 1.00 | Ca ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 228 | >10 ¹⁴ | 33 | 100.0 | 0.35 | 良好 | | | | |
| 22 | 2.0 | 1.00 | In ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 235 | >10 ¹⁴ | 31 | 100.0 | 0.36 | 良好 | | | | |
| 23 | 2.0 | 1.00 | WO ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 220 | >10 ¹⁴ | 36 | 100.0 | 0.34 | 良好 | | | | |
| 24 | 2.0 | 1.00 | Bi ₂ O ₃ | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 211 | >10 ¹⁴ | 38 | 100.0 | 0.35 | 良好 | | | | |
| 25 | 2.0 | 1.00 | PbO | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 217 | >10 ¹⁴ | 37 | 100.0 | 0.34 | 良好 | | | | |
| 26 | 2.0 | 1.00 | Sb ₂ O ₃ | 1.00 | CaH ₂ | 1.00 | Li ₂ O | 1.00 | 215 | >10 ¹⁴ | 35 | 100.0 | 0.33 | 良好 | | | | |
| 27 | 2.0 | 1.00 | CdO | 1.00 | CaH ₂ | 0.50 | Li ₂ O | 1.00 | 211 | >10 ¹⁴ | 34 | 100.0 | 0.32 | 良好 | | | | |

第10表-2

| 第 10 表 - 2 | | | | | | | | | | | | | | |
|------------|--------------------------------------|----------|---|----------------------|---|----------------------|--|----------------------|-------------|---------------------------|-----------|--------------------|------|-----|
| No. | Y ₂ O ₃ 重量部 | B 重量部 | 添 加 物 | | | | | 熱伝導率 W/mK | 絶縁抵抗 Ωcm | 堆 積 kg/mm ² | 相対密度 % | 表面粗度 Ra (μm) | 外觀 | |
| | | | | 重量部 | | 重量部 | | | | | | | | 重量部 |
| 28 | 1.0 | 0.5 | Al ₂ O ₃ + SiO ₂ | 1.00 | LaB ₆ | 1.00 | B ₂ O ₃ | 0.50 | 241 | >10 ¹⁴ | 36 | 100.0 | 0.33 | 良好 |
| 29 | 1.0 | 0.5 | GeO ₂ | 1.00 | LaB ₆ + CaH ₂ | 0.50 0.30 | B ₂ O ₃ | 0.50 | 243 | >10 ¹⁴ | 36 | 100.0 | 0.35 | 良好 |
| 30 | 2.0 | 1.0 | Al ₂ O ₃ | 1.00 | CaS | 0.50 | B ₂ O ₃ + Na ₂ O | 0.20 0.30 | 243 | >10 ¹⁴ | 36 | 100.0 | 0.33 | 良好 |
| 31 | 2.0 | 1.0 | Al ₂ O ₃ + WO ₃ | 1.00 | CaS + CaH ₂ | 0.20 0.30 | P ₂ O ₅ | 0.20 | 244 | >10 ¹⁴ | 34 | 100.0 | 0.35 | 良好 |
| 32 | 2.0 | 1.0 | CdO | 1.00 | CaS + CaH ₂ | 0.20 0.30 | B ₂ O ₃ + P ₂ O ₅ | 0.20 0.20 | 246 | >10 ¹⁴ | 33 | 100.0 | 0.34 | 良好 |
| 33 | 2.0 | 1.0 | CdO + ZnO | 0.40 0.40 | CdS + ZnS | 0.20 0.30 | B ₂ O ₃ + P ₂ O ₅ | 0.20 0.20 | 244 | >10 ¹⁴ | 39 | 100.0 | 0.32 | 良好 |
| 34 | 2.0 | 1.0 | Al ₂ O ₃ | 0.20 | CaS + CaH ₂ + Ca ₃ N ₂ | 0.20 0.20 0.20 | B ₂ O ₃ + SiO ₂ + Li ₂ O | 0.20 0.20 0.20 | 246 | >10 ¹⁴ | 40 | 100.0 | 0.35 | 良好 |
| 35 | 2.0 | 1.0 | Al ₂ O ₃ + In ₂ O ₃ + PbO | 1.00 0.01 0.01 | CaS + CaH ₂ + Ca ₃ N ₂ | 0.01 0.10 2.00 | B ₂ O ₃ + SiO ₂ + Li ₂ O | 0.30 0.01 0.02 | 248 | >10 ¹⁴ | 41 | 100.0 | 0.36 | 良好 |

第1頁の続き

| | | | |
|------|------|--------------|-----------------|
| ②発明者 | 山村卓 | 千葉県千葉市川崎町1番地 | 川崎製鉄株式会社技術研究本部内 |
| ②発明者 | 船橋敏彦 | 千葉県千葉市川崎町1番地 | 川崎製鉄株式会社技術研究本部内 |
| ②発明者 | 熊谷正人 | 千葉県千葉市川崎町1番地 | 川崎製鉄株式会社技術研究本部内 |

手続補正書 (自発)

平成2年6月11日

特許庁長官 吉田文毅 殿

1. 事件の表示

平成1年 特許願 第95385号

2. 発明の名称

窒化アルミニウム焼結体の製造方法

3. 補正をする者

事件との関係 特許出願人

神戸市中央区北本町通1丁目1番29号

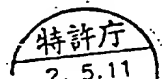
(125) 川崎製鉄株式会社

4. 代理人 〒105 803(508) 9104

東京都港区西新橋1丁目10番8号

第2クスグビル4階

弁理士(7917) 小杉佳男



5. 補正により増加する発明の数 なし

6. 補正の対象

明細書の『発明の詳細な説明』の欄。

7. 補正の内容

(1) 明細書の第20頁第11行目『A2N粒』の前に『2000℃を越えると、』を挿入する。